The Defense Mapping Agency

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DMA Technical Report

SUPPLEMENT TO DEPARTMENT OF DEFENSE WORLD GEODETIC SYSTEM 1984 TECHNICAL REPORT

PART II

PARAMETERS, FORMULAS, AND GRAPHICS FOR THE PRACTICAL APPLICATION OF WGS 84

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CHANGES TO DMA TR 8350.2-B,

SUPPLEMENT TO DEPARTMENT OF DEFENSE WORLD GEODETIC SYSTEM 1984 TECHNICAL REPORT, PART II - PARAMETERS, FORMULAS, AND GRAPHICS FOR THE PRACTICAL APPLICATION OF WGS 84, 1 December 1987.

The enclosed pages are changes as of 1 March 1989 which update both the first and second printings of the report.

Table 20.16

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- ED 50 (Cyprus) to WGS 84 -

$$\Delta\phi'' = -3.84288 + 0.09188\,U + 0.03581\,V - 0.07481\,UV$$

$$\Delta\lambda'' = -1.10294 - 0.04240\,U + 0.12748\,V - 0.32783\,UV^2 + 0.51023\,UV^3 - 0.01600\,V^7 - 0.1718\,U^3V^9$$

$$\Delta H_m = 24.430 - 5.719\,U + 0.778\,V + 5.631\,U^2 - 23.892\,UV + 18.980\,U^2V - 0.988\,V^3 + 106.027\,U^3V - 42.824\,U^4V - 323.655\,U^9V^2 + 2.261\,U^4V^9$$

<u>In the preceding equations</u>:

$U = K\,(\phi - 35)$
$V = K\,(\lambda - 33)$
$K = 0.78539816$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 16 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.5 m; λ: ±0.3 m; H (geodetic height): ±0.2 m

<u>Test Case</u>:

Input data for ED 50 (Cyprus) test point:	ϕ =	34°43'23.316"N	$\Delta\phi$ =	-3.885"
	λ =	32°28'06.026"E	$\Delta\lambda$ =	-1.126"
			ΔH =	23.64 m

[Revised: 1 March 1989]

Table 20.29

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Minna Datum* to WGS 84 -

$$\Delta\phi'' = 0.49461 - 0.69094\,U + 0.39940\,V - 7.44709\,U^3 - 1.82129\,U^2V - 2.92752\,UV^2 + 5.70789\,U^3V - 2.10838\,U^2V^2 - 6.88780\,UV^3 + 14.35602\,U^5 + 5.10389\,UV^4 + 6.18524\,U^6 + 8.62320\,UV^5 + 48.52705\,U^7V^2 - 0.49769\,V^9 - 11.39331\,U^4V^8$$

$$\Delta\lambda'' = -2.62435 - 0.21876\,U + 0.43678\,V + 0.35068\,UV - 1.53864\,U^2V - 0.46268\,UV^3 + 2.20240\,U^4V - 0.11456\,V^5 + 1.59485\,U^3V^4$$

$$\Delta H_m = 20.013 + 2.098\,U - 11.691\,V + 47.983\,U^2V - 60.195\,U^4V - 21.214\,U^2V^3 + 8.642\,V^5 - 12.588\,U^5V - 27.760\,U^3V^8$$

In the preceding equations:

$U = K\,(\phi - 10)$
$V = K\,(\lambda - 8)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 23 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±1.0 m; H (geodetic height): ±0.7 m

Test Case:

Input data for Minna Datum test point:	ϕ =	9°19'09.051"N	$\Delta\phi$ =	0.930"
	λ =	12°13'50.125"E	$\Delta\lambda$ =	-2.348"
			ΔH =	13.43m

* Nigeria

[Revised: 1 March 1989]

Table 20.31

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Alaska) to WGS 84 -

$$\Delta\phi'' = -2.08611 + 0.59833\,U + 0.52967\,V + 0.23473\,U^2 + 0.23563\,UV + 0.28672\,UV^2 + 0.27573\,V^3 + 0.19561\,U^4 - 0.15184\,U^3V - 0.21241\,U^2V^2 + 0.04891\,V^4 - 0.18860\,UV^4 - 0.17032\,V^5 - 0.05741\,UV^5 - 0.04292\,U^2V^5 + 0.02097\,V^7 - 0.01487\,U^2V^6 - 0.00384\,V^8 - 0.18402\,U^9 - 0.00188\,U^3V^7$$

$$\Delta\lambda'' = -8.19369 - 1.56665\,U + 0.73861\,V - 3.10809\,U^2 - 0.35323\,UV - 0.06926\,V^2 - 0.68114\,UV^2 - 0.32398\,V^3 + 0.74679\,U^4 + 0.43200\,U^3V + 4.24388\,U^2V^2 + 0.14065\,UV^3 - 0.30990\,U^2V^3 + 0.11365\,V^5 - 1.48566\,U^4V^2 - 1.96501\,U^2V^4 + 2.04229\,U^6V - 0.48255\,U^5V^2 + 0.09847\,UV^6 + 0.49313\,U^2V^6 - 1.00218\,U^8V - 0.02809\,U^2V^8 + 0.00054\,U^5V^9$$

$$\Delta H_m = 8.352 - 13.742\,U - 8.268\,V + 0.900\,V^2 + 5.340\,U^3 + 2.960\,UV^2 - 2.016\,V^3 + 5.087\,U^3V + 1.437\,UV^3 + 0.951\,V^5 - 2.461\,U^3V^4 - 1.560\,U^8 - 1.980\,U^7V - 0.205\,U^5V^3 + 0.094\,UV^8 - 2.885\,U^8V^2 - 0.011\,UV^9$$

In the preceding equations:

$U = K\,(\phi - 62)$
$V = K\,(\lambda - 208)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 85, 86, and 86 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.7 m; λ: ±1.7 m; H (geodetic height): ±1.2 m

Test Case:

Input data for NAD 27 (Alaska) test point:	ϕ =	64°31'09.064"N	$\Delta\phi$ =	-2.648"
	λ =	194°37'28.092"E	$\Delta\lambda$ =	-9.525"
			ΔH =	19.20 m

[Revised: 1 March 1989]

Table 20.32

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Canada) to WGS 84 -

$$\begin{aligned}\Delta\phi'' = {} & 0.79395 + 2.29199\,U + 0.27589\,V - 1.76644\,U^2 + 0.47743\,UV + 0.08421\,V^2 - 6.03894\,U^3 \\ & - 3.55747\,U^2V - 1.81118\,UV^2 - 0.20307\,V^3 + 7.75815\,U^4 - 3.10170\,U^3V + 3.58363\,U^2V^2 \\ & - 1.31086\,UV^3 - 0.45916\,V^4 + 14.27239\,U^5 + 3.28815\,U^4V + 1.35742\,U^2V^3 + 1.75323\,UV^4 \\ & + 0.44999\,V^5 - 19.02041\,U^4V^2 - 1.01631\,U^2V^4 + 1.47331\,UV^5 + 0.15181\,V^6 + 0.41614\,U^2V^5 \\ & - 0.80920\,UV^6 - 0.18177\,V^7 + 5.19854\,U^4V^4 - 0.48837\,UV^7 - 0.01473\,V^8 - 2.26448\,U^9 \\ & - 0.46457\,U^2V^7 + 0.11259\,UV^8 + 0.02067\,V^9 + 47.64961\,U^8V^2 + 0.04828\,UV^9 + 36.38963\,U^9V^2 \\ & + 0.06991\,U^4V^7 + 0.08456\,U^3V^8 + 0.09113\,U^2V^9 + 5.93797\,U^7V^5 - 2.36261\,U^7V^6 + 0.095775\,U^5V^8\end{aligned}$$

$$\begin{aligned}\Delta\lambda'' = {} & - 1.36099 + 3.61796\,V - 3.97703\,U^2 + 3.09705\,UV - 1.15866\,V^2 - 13.28954\,U^3 - 3.15795\,U^2V \\ & + 0.68405\,UV^2 - 0.50303\,V^3 - 8.81200\,U^3V - 2.17587\,U^2V^2 - 1.49513\,UV^3 + 0.84700\,V^4 \\ & + 31.42448\,U^5 - 14.67474\,U^3V^2 + 0.65640\,UV^4 + 17.55842\,U^6 + 6.87058\,U^4V^2 - 0.21565\,V^6 \\ & + 62.18139\,U^5V^2 + 1.78687\,U^3V^4 + 2.74517\,U^2V^5 - 0.30085\,UV^6 + 0.04600\,V^7 + 63.52702\,U^6V^2 \\ & + 7.83682\,U^5V^3 + 9.59444\,U^3V^5 + 0.01480\,V^8 + 10.51228\,U^4V^5 - 1.42398\,U^2V^7 - 0.00834\,V^9 \\ & + 5.23485\,U^7V^3 - 3.18129\,U^3V^7 + 8.45704\,U^9V^2 - 2.29333\,U^4V^7 + 0.14465\,U^2V^9 + 0.29701\,U^3V^9 \\ & + 0.17655\,U^4V^9\end{aligned}$$

$$\begin{aligned}\Delta H_m = {} & - 26.806 + 9.266\,U - 5.857\,V + 14.794\,U^2 + 3.497\,UV + 9.600\,V^2 - 7.664\,UV^2 - 40.040\,U^2V^2 \\ & - 3.439\,V^4 + 14.592\,U^2V^3 - 23.902\,U^5V + 15.246\,U^4V^2 + 18.445\,U^2V^4 + 0.770\,V^6 - 130.424\,U^6V \\ & - 11.874\,U^2V^5 - 100.769\,U^7V - 3.165\,U^2V^6 - 0.182\,UV^7 - 0.066\,V^8 + 2.404\,U^2V^7 + 0.073\,UV^8 \\ & - 0.074\,U^2V^9\end{aligned}$$

[Revised: 1 March 1989]

Table 20.41

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Qatar National Datum* to WGS 84 -

$$\Delta\phi'' = 2.47363 + 0.08786\,U + 0.14283\,U^2 + 0.04380\,UV + 0.07142\,V^2 - 0.08879\,UV^2 - 0.11089\,U^5 - 0.06321\,U^3V^4 + 0.01669\,U^9$$

$$\Delta\lambda'' = -2.80439 + 0.10489\,V + 0.02697\,V^2 - 1.10721\,U^2V^2 + 2.88786\,U^2V^3 - 0.06281\,U^5V - 2.59921\,U^3V^6$$

$$\Delta H_m = -28.376 + 2.381\,U - 1.126\,U^2 + 3.095\,V^2 - 4.112\,U^3V^3 - 13.156\,V^7 - 2.048\,U^8 + 1.618\,U^9 + 18.689\,UV^8$$

In the preceding equations:

$U = K\,(\phi - 25)$
$V = K\,(\lambda - 51)$
$K = 1.04719754$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 15 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.3 m; λ: ±0.2 m; H (geodetic height): ±0.2 m

Test Case:

Input data for Qatar National Datum test point:	ϕ =	24°34'55.061"N	$\Delta\phi$ =	2.465"
	λ =	50°59'06.940"E	$\Delta\lambda$ =	-2.806"
			ΔH =	-29.64 m

* Qatar Island (Persian Gulf)

[Revised: 1 March 1989]

Table 23.21

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Kandawala Datum* -

$$N_m = -0.979 + 1.853\,U - 3.443\,U^2 + 2.523\,U^3 - 5.423\,U^2V - 5.278\,V^3 + 3.965\,U^4V^3 - 0.899\,U^7V^2 + 5.225\,U^2V^9$$

In the preceding equation:

$U = K\,(\phi - 7)$
$V = K\,(\lambda - 80)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Kandawala Datum geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.4 meter; 17 sites involved in the comparison.

Test Case:

Input data for Kandawala Datum test point:	ϕ = 7°37'02.730"N λ = 81°40'49.750"E	N = -4.55 m (Everest Ellipsoid)

* Sri Lanka; Everest Ellipsoid

[Revised: 1 March 1989]

Table 23.27

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Nahrwan Datum* -

$$N_m = 7.464 - 3.286\ U - 3.024\ V - 3.944\ U^2 - 4.720\ V^2 - 2.019\ U^3 - 1.613\ V^3$$

In the preceding equation:

$U = K\ (\phi - 23)$
$V = K\ (\lambda - 57)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Nahrwan Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 19 sites involved in the comparison.

Test Case:

Input data for Nahrwan Datum test point:	ϕ =	24°58'07.671"N	N = 1.11 m (Clarke 1880 Ellipsoid)
	λ =	55°00'07.720"E	

* Masirah Island (Oman) and United Arab Emirates only (Clarke 1880 Ellipsoid). Contact DMA (see PREFACE) if data in this form is needed for Saudi Arabia.

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This technical report, Part II of a three-part supplement to the Department of Defense (DoD) World Geodetic System 1984 (WGS 84) Technical Report, DMA TR 8350.2, presents the parameters, formulas, and graphics for the practical application of WGS 84. The development of WGS 84 was initiated for the purpose of providing the more accurate geodetic and gravitational data required by DoD navigation and weapon systems. The new system represents the Defense Mapping Agency's modeling of the earth from a geometric, geodetic, and gravitational standpoint using data, techniques, and technology available through early 1984.

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18. SUBJECT TERMS

Angular Velocity of the Earth, Astronomic Nutation, Average Value of Theoretical Gravity, Besselian Epoch, Celestial Ephemeris Pole, Conventional Inertial System, Conventional Terrestrial Pole, Conventional Terrestrial System, Coordinates, Coordinate Accuracy, Coordinate Systems, Datums, Datum Shifts, Datum Transformations, Datum Transformation Multiple Regression Equations, Degree Variances, Dynamical Ellipticity, Earth Gravitational Constant, Earth Gravitational Model, Earth's Mass, Earth's Moments of Inertia, Earth's Rotation, Ellipsoid Constants, Ellipsoid Flattening, Ellipsoidal Gravity Formula, Ellipsoid Parameters, Ellipsoid Semimajor Axis, Equatorial Gravity, Flattening, General Precession, Geodesy, Geodetic, Geodetic Heights, Geoids, Geoid Heights, Geoid Undulations, Gravitation, Gravitational Coefficients, Gravitational Model, Gravitational Potential, Gravity, Gravity Anomaly Degree Variances, Gravity Formula, Gravity Potential, Instantaneous Terrestrial System, Julian Epoch, Local Datums, Local Geodetic Datums, Local Geodetic Systems, Local Geodetic System-to-WGS 84 Datum Shifts, Local Geodetic System-to-WGS 84 Datum Transformations, Lumped Gravitational Coefficients, Mass of the Earth's Atmosphere, Mean Datum Shifts, Molodensky Datum Transformation Formulas, Multiple Regression Equations, NAVSTAR GPS-Derived WGS 84 Coordinates, NSWC 9Z-2 to WGS 84 Transformation, Normal Gravity, Normal Gravity Formula, Normal Gravity Potential, Nutation, Polar Motion, Precession, Reference Frames, Reference Systems, Seven Parameter Datum Transformation, Theoretical Gravity, Theoretical Gravity Formula, Theoretical Gravity Potential, World Geodetic System, World Geodetic System 1972, WGS 72, WGS 72-to-WGS 84 Transformation, World Geodetic System 1984, WGS 84, WGS 84 Coordinates, WGS 84 Coordinate Accuracy, WGS 84 Coordinate System, WGS 84 Ellipsoid, WGS 84 Ellipsoidal Gravity Formula, WGS 84 Earth Gravitational Model, WGS 84 Geoid, WGS 84-to-Local Geodetic System Datum Transformations, WGS 84 Reference Frame, WGS 84 Reference System.

THE DEFENSE MAPPING AGENCY

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DMA maintains close liaison with civilian agencies of the United States Government engaged in MC&G activities and works closely with various national and international scientific and operational organizations in the MC&G field.

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The Committee expresses its appreciation to Mrs. Carol A. Malyevac and Mr. C. Harris Seay, NSWC, and Mr. Louis Abramovitz, Mr. L. Thomas Appelbaum, Mr. John A. Bangert, Mr. James M. Barth, Mr. Archie E. Carlson, Mr. Robert E. Catulle, Mrs. Inez J. Dimitrijevich, Mr. Carl E. Draper, Mrs. Mary S. Ealum, Mrs. Joyce E. Fox, Mr. David M. Gleason, Mr. John L. Goodwin, Mr. John Hopkins, Mr. Donovan N. Huber, Miss Beatrice Jernigan, Miss Martha R. Lahr, Mrs. Mary M. Martie, Mr. Kenneth Nelson, Mr. Robert M. Perlman, Mr. Donald A. Richardson, Mr. Melvin E. Shultz, Mr. Neil J. Simmons, Dr. Randall W. Smith, Dr. William L. Stein, Mr. George T. Stentz, Mr. Balfour R. Sutton, Mr. Robert W. Valska, Mr. Dennis H. Van Hee, and Mr. James F. Vines of DMA for their assistance. The many contributions of other supporting personnel of DMA and NSWC are also gratefully acknowledged. In addition, a special thanks is extended to the many organizations and individuals in the United States and abroad who provided data and technical expertise in support of the WGS 84 development effort. In particular, Mr. John A. Gergen, Mrs. Elizabeth B. Wade, and Mr. Larry D. Hothem, of the National Geodetic Survey (NGS), and Dr. Dennis D. McCarthy, of the United States Naval Observatory (USNO), are cited for their support.

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WASHINGTON, DC 20305-3000

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Supplement to Department of Defense
World Geodetic System 1984 Technical Report:

Part II - Parameters, Formulas, and Graphics
for the Practical Application of WGS 84

FOREWORD

1. This technical report, Part II of a three-part supplement to the Department of Defense (DoD) World Geodetic System 1984 (WGS 84) Technical Report, DMA TR 8350.2, presents the parameters, formulas, and graphics for the practical application of WGS 84. WGS 84 was initiated to provide more accurate geodetic and gravitational data required by DoD navigation and weapon systems. The new system represents the Defense Mapping Agency's (DMA) geometric, geodetic, and gravitational modeling of the Earth using data, techniques, and technology available through early 1984.

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MARCUS J. BOYLE
Colonel, USAF
Chief of Staff

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PREFACE

This technical report is Part II of a three-part supplement to the Department of Defense (DoD) World Geodetic System 1984 (WGS 84) Technical Report, DMA TR 8350.2. The latter provides a brief discussion of WGS 84 and its relationships with local geodetic systems. Part I of the supplement discusses WGS 84 and the methods, techniques, and data used in developing the parameters and products that define it. Considerable space is devoted in Part I to the discussion of the WGS 84 Reference Frame, Ellipsoid, Ellipsoidal Gravity Formula, Earth Gravitational Model, Geoid, and methods and procedures for obtaining WGS 84 coordinates. This report (Part II of the supplement) contains final values for the WGS 84 defining parameters and products, their accuracies, and formulas relevant to the implementation. Most of Part II consists of graphical and tabular materials for converting 83 local geodetic systems to WGS 84. Part II is largely self-contained in that the contents, with a few exceptions, completely define WGS 84. Although WGS 84 is essentially an unclassified system, the associated Earth Gravitational Model (and its corresponding geoid) above degree (n) and order (m) 18 are CLASSIFIED. These materials comprise Part III of the supplement, which treats the CLASSIFIED portion of WGS 84.

Requesters requiring additional information, data, or Part III of the supplement should forward their request to:

Director
Defense Mapping Agency
ATTN: PR
Building 56
United States Naval Observatory
Washington, DC 20305-3000

Similarly, requesters requiring the positioning of sites of interest directly in WGS 84 via Satellite Point Positioning utilizing ground-based receivers should transmit their requirements to the above address. Other WGS 84-related requests or questions may also be referred there.

Since WGS 84 is comprised of a consistent set of parameters, organizations involved in a DoD application should not make a substitution for any of the WGS 84-related parameters in an attempt to improve the accuracy. Such a substitution may lead to less accurate WGS 84 products.

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SECTION 1

WGS 84
EARTH-CENTERED, EARTH-FIXED (ECEF) COORDINATE SYSTEM* (AND ASSOCIATED REFERENCE FRAMES)

---

* ANALOGOUS TO THE BIH-DEFINED CONVENTIONAL TERRESTRIAL SYSTEM (CTS), OR BTS, 1984.0.

Origin = Earth's Center of Mass ≡ Geometric Center of WGS 84 Ellipsoid

Z-Axis = Parallel to the Direction of the Conventional Terrestrial Pole (CTP) for Polar Motion, as Defined by the Bureau International de L'Heure (BIH) on the Basis of the Coordinates Adopted for the BIH Stations ≡ Rotation Axis (Z-Axis) of WGS 84 Ellipsoid

X-Axis = Intersection of the WGS 84 Reference Meridian Plane and the Plane of the CTP's Equator, the Reference Meridian Being Parallel to the Zero Meridian Defined by the BIH on the Basis of the Coordinates Adopted for the BIH Stations ≡ X-Axis of WGS 84 Ellipsoid.

Y-Axis = Completes a Right-Handed, Earth Centered, Earth Fixed (ECEF) Orthogonal Coordinate System, Measured in the Plane of the CTP Equator, 90° East of the X-Axis ≡ Y-Axis of WGS 84 Ellipsoid

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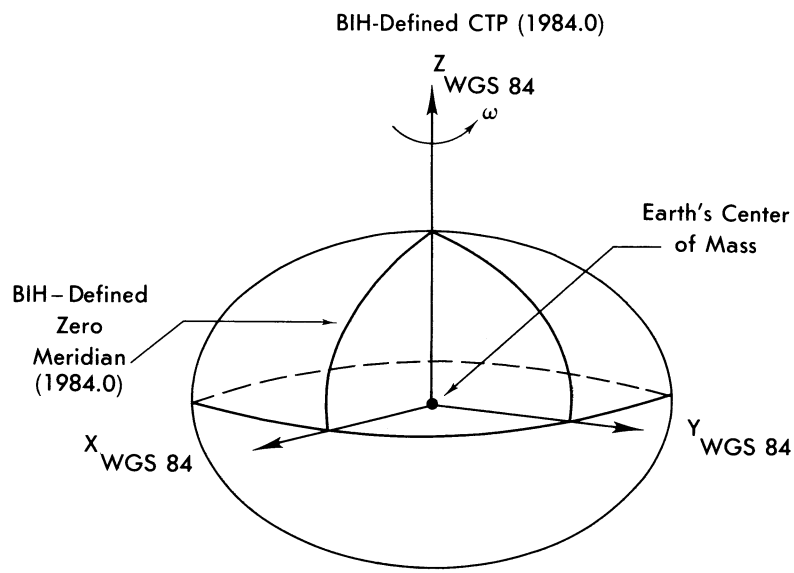
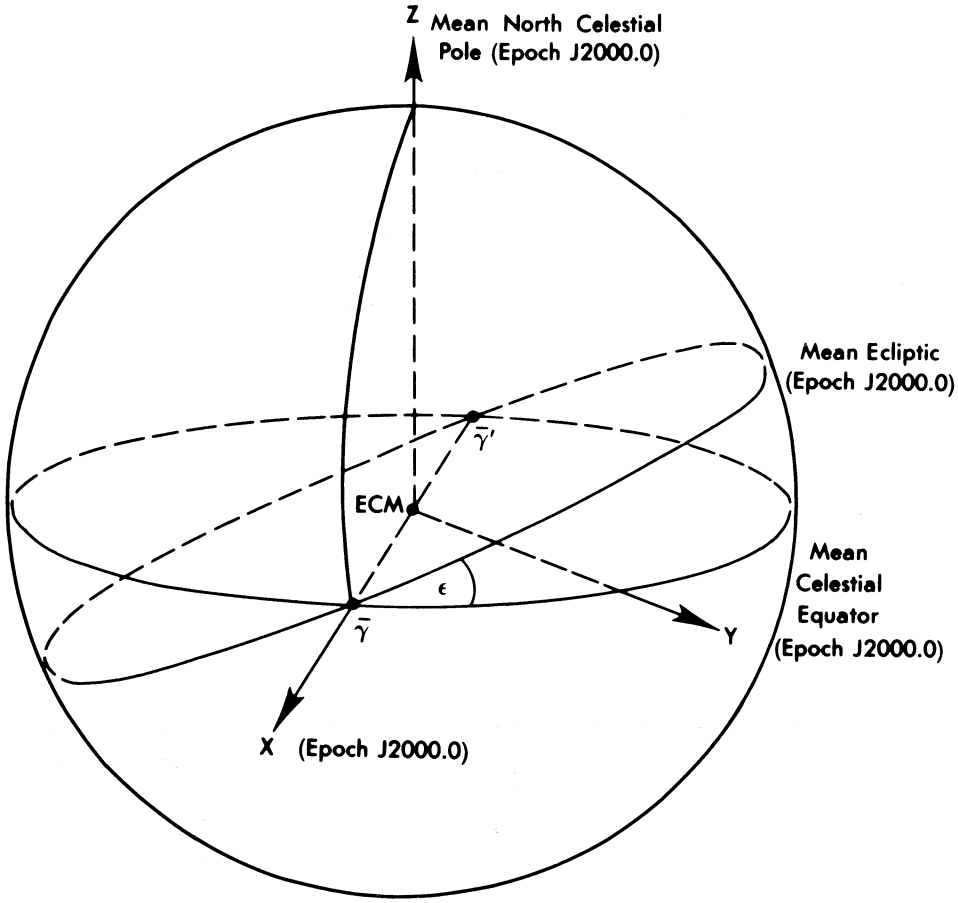


Figure 1.1. WGS 84 Reference Frame



$\bar{\gamma}$ = Mean Vernal Equinox (Epoch J2000.0)
$\bar{\gamma}'$ = Mean Autumnal Equinox (Epoch J2000.0)
ECM = Earth's Center of Mass
ϵ = Obliquity of the Ecliptic
$\epsilon \approx 23°27'$

Figure 1.2. Pictorial Definition of the Conventional Inertial System [Stellar (FK5), Epoch J2000.0]

Three Reference Systems

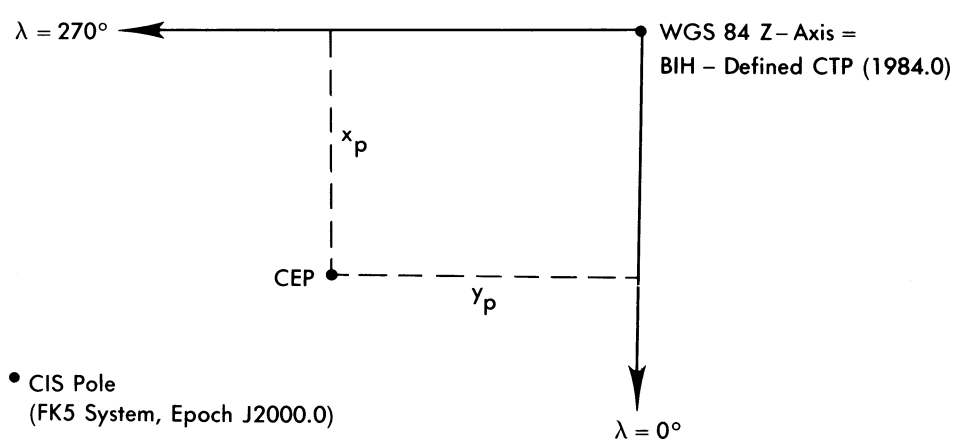
- Conventional Terrestrial System (CTS) = WGS 84
- Instantaneous Terrestrial System (ITS) = Not Realizable in a Measurement Sense. However, an Approximation to the ITS Pole, the Celestial Epheremis Pole (CEP), is Used Instead.
- Conventional Inertial System (CIS)

CTS (WGS 84) = [A] [B] [C] [D] CIS

Rotation Matrices:

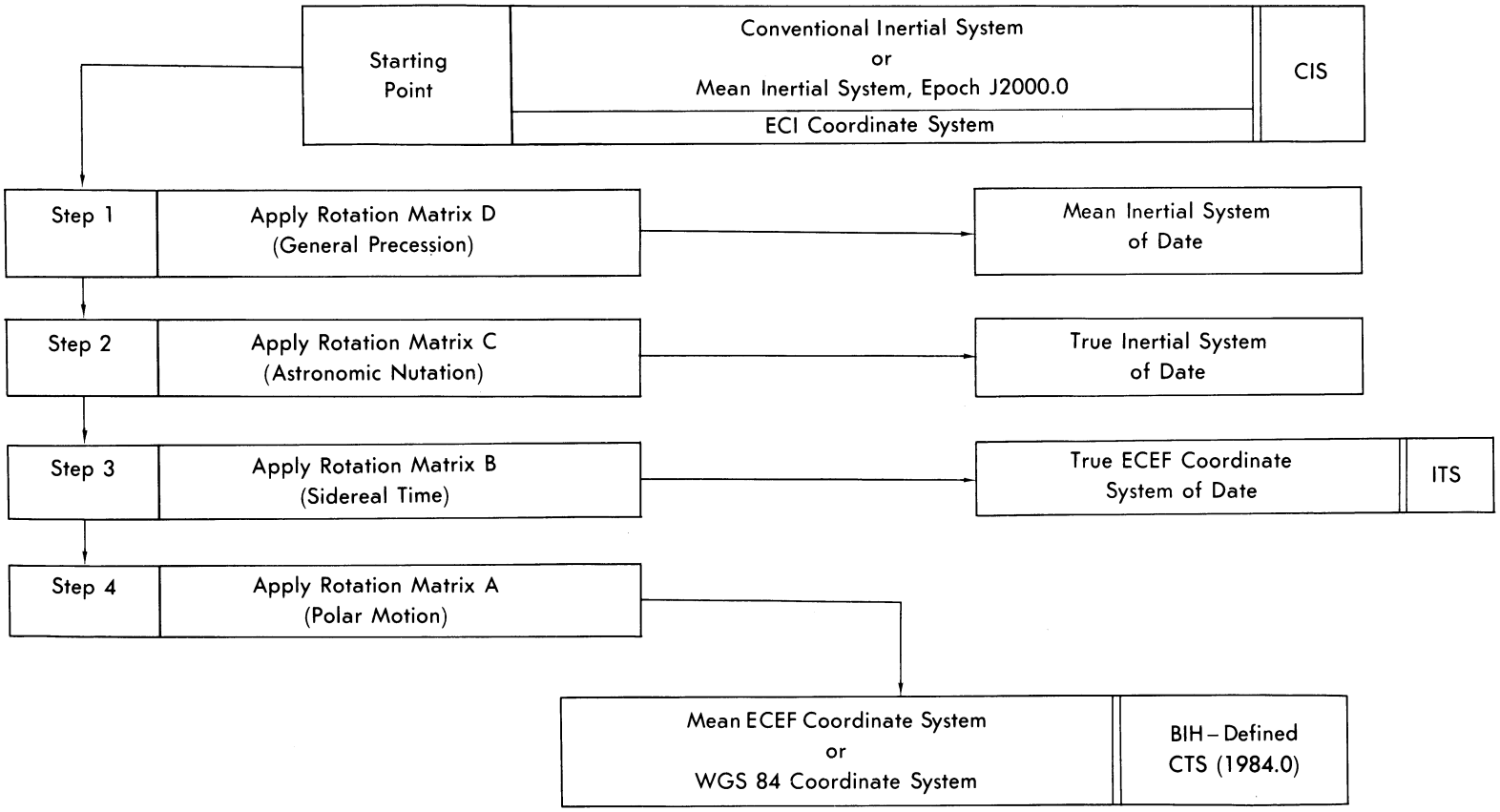
D = Precession
C = Astronomic Nutation
B = Sidereal Time
A = Polar Motion

[See Appendix to Reference 2.]



[x_p, y_p = Polar Motion Parameters; λ = Astronomic Longitude]

Figure 1.3. Mathematical and Pictorial Relationship Between WGS 84 and Associated Reference Frames (Systems)



[See Appendix to Reference 2.]

Figure 1.4. CIS-to-WGS 84 (CIS-to-CTS) Transformation

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SECTION 2

WGS 84 ELLIPSOID

- DEFINING PARAMETERS, ASSOCIATED CONSTANTS, ETC. -

Table 2.1

WGS 84 Ellipsoid
- Four Defining Parameters -

Parameters	Notation	Magnitude	Accuracy (1σ)
Semimajor Axis	a	6378137 m	±2 m
Normalized Second Degree Zonal Harmonic Coefficient of the Gravitational Potential	$\bar{C}_{2,0}$	$-484.16685 \times 10^{-6}$	$\pm 1.30 \times 10^{-9}$
Angular Velocity of the Earth	ω	7292115×10^{-11} rad s^{-1}	$\pm 0.1500 \times 10^{-11}$ rad s^{-1}
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Included)	GM	3986005×10^{8} m^3 s^{-2}	$\pm 0.6 \times 10^{8}$ m^3 s^{-2}
Parameter Values for Special Applications			
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Not Included)	GM'	3986001.5×10^{8} m^3 s^{-2}	$\pm 0.6 \times 10^{8}$ m^3 s^{-2}
Angular Velocity of the Earth (In a Precessing Reference Frame)	ω^*	$(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15}\ T_U)$ rad s^{-1}	$\pm 0.1500 \times 10^{-11}$ rad s^{-1}

T_U = Julian Centuries From Epoch J2000.0

$T_U = d_U/36525$

d_U = Number of Days of Universal Time (UT) From Julian Date (JD) 2451545.0 UT1, Taking on Values of ±0.5, ±1.5, ±2.5, ..

d_U = JD - 2451545

Table 2.2

WGS 84 Ellipsoid
- Derived Geometric Constants -

Constants	Notation	Value
Flattening (Ellipticity)	f	1/298.257223563 (0.00335281066474)
Semiminor Axis	b	6356752.3142 m
First Eccentricity	e	0.0818191908426
First Eccentricity Squared	e^2	0.00669437999013
Second Eccentricity	e'	0.0820944379496
Second Eccentricity Squared	e'^2	0.00673949674227
Linear Eccentricity	E	521854.0084 m
Polar Radius of Curvature	c	6399593.6258 m
Axis Ratio	b/a	0.996647189335
Mean Radius of Semiaxes	R_1	6371008.7714 m
Radius of Sphere With Equal Area	R_2	6371007.1809 m
Radius of Sphere With Equal Volume	R_3	6371000.7900 m

Table 2.3

WGS 84 Ellipsoid
- Derived Physical Constants -

Constants	Notation	Value
Theoretical (Normal) Gravity Potential of the Ellipsoid	U_o	62636860.8497 $m^2\ s^{-2}$
Theoretical (Normal) Gravity at the Equator (on the Ellipsoid)	γ_e	9.7803267714 $m\ s^{-2}$
Theoretical (Normal) Gravity at the Poles (on the Ellipsoid)	γ_p	9.8321863685 $m\ s^{-2}$
Mean Value of Theoretical (Normal) Gravity	$\bar{\gamma}$	9.7976446561 $m\ s^{-2}$
Theoretical (Normal) Gravity Formula Constant	k	0.00193185138639
Mass of Earth (Includes the Atmosphere)	M	5.9733328×10^{24} kg
$m = \omega^2 a^2 b/GM$	m	0.00344978600313

Table 2.4
Relevant Miscellaneous Constants
and Conversion Factors

Constant	Symbol	Numerical Value
Velocity of Light (in a Vacuum)	c	299792458 m s^{-1}
Dynamical Ellipticity	H	1/305.4413
Earth's Angular Velocity [for Satellite Applications; See Equation (3-22) of Reference 2.]	ω^*	$(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15}\ T_U)$ rad s^{-1}
Universal Constant of Gravitation	G	$6.673 \times 10^{-11} m^3 s^{-2} kg^{-1}$
GM of the Earth's Atmosphere	GM_A	$3.5 \times 10^8 m^3 s^{-2}$
Earth's Gravitational Constant (Excluding the Mass of the Earth's Atmosphere)	GM'	$3986001.5 \times 10^8 m^3 s^{-2}$
Earth's Principal Moments of Inertia (Dynamic Solution)	A	8.0091029×10^{37} kg m^2
	B	8.0092559×10^{37} kg m^2
	C	8.0354872×10^{37} kg m^2

Conversion Factors	
1 Meter	= 3.28083333333 US Survey Feet
1 Meter	= 3.28083989501 International Feet
1 International Foot	= 0.3048 Meter (Exact)
1 US Survey Foot	= 1200/3937 Meter (Exact)
1 US Survey Foot	= 0.30480060960 Meter
1 Nautical Mile	= 1852 Meters (Exact) = 6076.10333333 US Survey Feet = 6076.11548556 International Feet
1 Statute Mile	= 1609.344 Meters (Exact) = 5280 International Feet (Exact)

T_U = Julian Centuries from Epoch J2000.0

Table 2.5

Differences
- WGS 84 And WGS 72 Ellipsoid Parameters -

Parameters	Notation	WGS 84	WGS 72 [4]	Differences*
Semimajor Axis	a	6378137 m	6378135 m	2 m
Normalized Second Degree Zonal	$\bar{C}_{2,0}$	$-484.16685 \times 10^{-6}$	-484.1605×10^{-6}	-0.00635×10^{-6}
Angular Velocity	ω	7292115×10^{-11} rad s^{-1}	$7292115.147 \times 10^{-11}$ rad s^{-1}	-0.147×10^{-11} rad s^{-1}
Gravitational Constant (Mass of Earth's Atmosphere Included)	GM	3986005×10^{8} m^3 s^{-2}	3986008×10^{8} m^3 s^{-2}	-3×10^{8} m^3 s^{-2}
Gravitational Constant (Without Mass of Earth's Atmosphere)	GM'	3986001.5×10^{8} m^3 s^{-2}	3986005×10^{8} m^3 s^{-2}	-3.5×10^{8} m^3 s^{-2}
Angular Velocity (Precessing Reference Frame)	ω^*	$(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15}\ T_U)$ rad s^{-1} [See Table 2.1]	----	----
Flattening	f	1/298.257223563	1/298.26	0.3121057×10^{-7}
Semiminor Axis	b	6356752.3142 m	6356750.5 m	1.8142 m
First Eccentricity Squared	e^2	0.00669437999013	0.006694317778	0.6221213×10^{-7}

* WGS 84 Minus WGS 72

Table 2.6

Arc Distances on the WGS 84 Ellipsoid Corresponding to One Arc Second of Geodetic Latitude and Geodetic Longitude

Geodetic Latitude	Arc Distance		Geodetic Latitude	Arc Distance	
	S_ϕ	S_λ		S_ϕ	S_λ
0°	30.7151 m	30.9221 m	50°	30.8970 m	19.9155 m
5	30.7174	30.8052	55	30.9232	17.7761
10	30.7244	30.4554	60	30.9479	15.5000
15	30.7357	29.8751	65	30.9702	13.1043
20	30.7512	29.0686	70	30.9895	10.6074
25	30.7702	28.0417	75	31.0051	8.0283
30	30.7923	26.8017	80	31.0167	5.3871
35	30.8168	25.3578	85	31.0237	2.7040
40	30.8430	23.7205	90	31.0261	0.0000
45	30.8699	21.9019			

S_ϕ = Meters in One Arc Second of Geodetic Latitude (Along Meridians of Longitude; WGS 84 Ellipsoid)

S_λ = Meters in One Arc Second of Geodetic Longitude (Along Parallels of Latitude; WGS 84 Ellipsoid)

Table 2.7

WGS 84 Ellipsoid

- Geocentric Radius and Radii of Curvature -

Geodetic Latitude (Degrees)	Geocentric Radius (Meters)	Radius of Curvature (Meters)	
		In the Meridian	In the Prime Vertical
0	6378137.0000	6335439.3273	6378137.0000
1	6378130.5409	6335458.7045	6378143.5026
2	6378111.1715	6335516.8129	6378163.0025
3	6378078.9145	6335613.5837	6378195.4764
4	6378033.8085	6335748.9017	6378240.8852
5	6377975.9070	6335922.6064	6378299.1746
6	6377905.2787	6336134.4912	6378370.2744
7	6377822.0077	6336384.3044	6378454.0995
8	6377726.1928	6336671.7491	6378550.5491
9	6377617.9481	6336996.4835	6378659.5074
10	6377497.4021	6337358.1216	6378780.8437
11	6377364.6984	6337756.2331	6378914.4121
12	6377219.9947	6338190.3444	6379060.0523
13	6377063.4634	6338659.9389	6379217.5892
14	6376895.2907	6339164.4574	6379386.8336
15	6376715.6771	6339703.2990	6379567.5820
16	6376524.8365	6340275.8217	6379759.6172
17	6376322.9964	6340881.3429	6379962.7080
18	6376110.3976	6341519.1405	6380176.6104
19	6375887.2938	6342188.4534	6380401.0668
20	6375653.9513	6342888.4825	6380635.8071

Table 2.7 (Cont'd)

WGS 84 Ellipsoid

- Geocentric Radius and Radii of Curvature -

Geodetic Latitude (Degrees)	Geocentric Radius (Meters)	Radius of Curvature (Meters)	
		In the Meridian	In the Prime Vertical
21	6375410.6488	6343618.3916	6380880.5487
22	6375157.6772	6344377.3084	6381134.9968
23	6374895.3390	6345164.3252	6381398.8447
24	6374623.9481	6345978.5003	6381671.7746
25	6374343.8296	6346818.8587	6381953.4572
26	6374055.3189	6347684.3936	6382243.5527
27	6373758.7621	6348574.0671	6382541.7112
28	6373454.5151	6349486.8118	6382847.5726
29	6373142.9430	6350421.5317	6383160.7676
30	6372824.4203	6351377.1037	6383480.9177
31	6372499.3300	6352352.3787	6383807.6359
32	6372168.0634	6353346.1832	6384140.5270
33	6371831.0193	6354357.3200	6384479.1883
34	6371488.6040	6355384.5707	6384823.2098
35	6371141.2307	6356426.6959	6385172.1749
36	6370789.3185	6357482.4377	6385525.6607
37	6370433.2928	6358550.5203	6385883.2387
38	6370073.5841	6359629.6521	6386244.4751
39	6369710.6277	6360718.5272	6386608.9316
40	6369344.8632	6361815.8264	6386976.1657

Table 2.7 (Cont'd)

WGS 84 Ellipsoid

- Geocentric Radius and Radii of Curvature -

Geodetic Latitude (Degrees)	Geocentric Radius (Meters)	Radius of Curvature (Meters)	
		In the Meridian	In the Prime Vertical
41	6368976.7342	6362920.2195	6387345.7313
42	6368606.6873	6364030.3664	6387717.1791
43	6368235.1720	6365144.9187	6388090.0576
44	6367862.6397	6366262.5217	6388463.9130
45	6367489.5439	6367381.8156	6388838.2901
46	6367116.3386	6368501.4376	6389212.7331
47	6366743.4789	6369620.0231	6389586.7856
48	6366371.4195	6370736.2075	6389959.9916
49	6366000.6147	6371848.6282	6390331.8958
50	6365631.5175	6372955.9257	6390702.0442
51	6365264.5795	6374056.7459	6391069.9849
52	6364900.2496	6375149.7413	6391435.2682
53	6364538.9744	6376233.5727	6391797.4477
54	6364181.1968	6377306.9112	6392156.0804
55	6363827.3557	6378368.4396	6392510.7274
56	6363477.8860	6379416.8540	6392860.9546
57	6363133.2170	6380450.8658	6393206.3329
58	6362793.7729	6381469.2028	6393546.4391
59	6362459.9716	6382470.6113	6393880.8561
60	6362132.2244	6383453.8572	6394209.1738

Table 2.7 (Cont'd)

WGS 84 Ellipsoid

- Geocentric Radius and Radii of Curvature -

Geodetic Latitude (Degrees)	Geocentric Radius (Meters)	Radius of Curvature (Meters)	
		In the Meridian	In the Prime Vertical
61	6361810.9354	6384417.7282	6394530.9893
62	6361496.5012	6385361.0346	6394845.9074
63	6361189.3100	6386282.6116	6395153.5412
64	6360889.7416	6387181.3202	6395453.5128
65	6360598.1664	6388056.0488	6395745.4533
66	6360314.9452	6388905.7150	6396029.0037
67	6360040.4289	6389729.2663	6396303.8151
68	6359774.9577	6390525.6823	6396569.5492
69	6359518.8607	6391293.9754	6396825.8788
70	6359272.4556	6392033.1923	6397072.4882
71	6359036.0485	6392742.4153	6397309.0735
72	6358809.9330	6393420.7633	6397535.3430
73	6358594.3901	6394067.3932	6397751.0178
74	6358389.6878	6394681.5011	6397955.8318
75	6358196.0808	6395262.3228	6398149.5323
76	6358013.8102	6395809.1355	6398331.8802
77	6357843.1028	6396321.2581	6398502.6506
78	6357684.1714	6396798.0529	6398661.6324
79	6357537.2140	6397238.9255	6398808.6294
80	6357402.4138	6397643.3264	6398943.4599

Table 2.7 (Cont'd)

WGS 84 Ellipsoid

- Geocentric Radius and Radii of Curvature -

Geodetic Latitude (Degrees)	Geocentric Radius (Meters)	Radius of Curvature (Meters)	
		In the Meridian	In the Prime Vertical
81	6357279.9389	6398010.7513	6399065.9574
82	6357169.9422	6398340.7417	6399175.9705
83	6357072.5608	6398632.8861	6399273.3632
84	6356987.9162	6398886.8197	6399358.0151
85	6356916.1143	6399102.2255	6399429.8215
86	6356857.2446	6399278.8347	6399488.6937
87	6356811.3806	6399416.4267	6399534.5589
88	6356778.5796	6399514.8296	6399567.3603
89	6356758.8826	6399573.9206	6399587.0574
90	6356752.3142	6399593.6258	6399593.6258

SECTION 3

WGS 84

ELLIPSOIDAL GRAVITY FORMULA

Table 3.1

WGS 84

Ellipsoidal Gravity Formula

Provides Gravity Values at (on) the Surface of the WGS 84 Ellipsoid
Notation γ = Theoretical acceleration of a unit test mass due to gravity. γ_e = Theoretical acceleration at the equator (on the WGS 84 Ellipsoid) of a unit test mass due to gravity. k = Constant $k = (b\gamma_p/a\gamma_e)-1$ a = Semimajor axis (WGS 84 Ellipsoid) b = Semiminor axis (WGS 84 Ellipsoid) γ_p = Theoretical gravity at the poles (on the WGS 84 Ellipsoid) ϕ = Geodetic latitude. e^2 = First eccentricity squared (WGS 84 Ellipsoid).
Analytical Form $\gamma = \gamma_e (1 + k \sin^2\phi) / (1 - e^2 \sin^2\phi)^{1/2}$
Numerical Form $\gamma = 978032.67714 (1 + 0.00193185138639 \sin^2\phi) / (1-0.00669437999013 \sin^2\phi)^{1/2}$ milligals
1 milligal = An acceleration due to gravity of 1×10^{-3} centimeters/second^2.

Table 3.2

Values of Theoretical Gravity
- Surface of WGS 84 Ellipsoid -

Geodetic Latitude	Theoretical Gravity (Milligals)	Geodetic Latitude	Theoretical Gravity (Milligals)	Geodetic Latitude	Theoretical Gravity (Milligals)
0°	978032.67714				
1	978034.24974	31°	979403.86004	61°	981995.59523
2	978038.96567	32	979484.30639	62	982071.68403
3	978046.81924	33	979566.21467	63	982146.01155
4	978057.80102	34	979649.38295	64	982218.48652
5	978071.89781	35	979733.74468	65	982289.01996
6	978089.09264	36	979819.19757	66	982357.52520
7	978109.36485	37	979905.63796	67	982423.91805
8	978132.69006	38	979992.96095	68	982488.11691
9	978159.04021	39	980081.06051	69	982550.04280
10	978188.38360	40	980169.82963	70	982609.61957
11	978220.68492	41	980259.16044	71	982666.77388
12	978255.90532	42	980348.94434	72	982721.43539
13	978294.00240	43	980439.07211	73	982773.53680
14	978334.93030	44	980529.43408	74	982823.01394
15	978378.63975	45	980619.92024	75	982869.80585
16	978425.07811	46	980710.42038	76	982913.85487
17	978474.18944	47	980800.82421	77	982955.10672
18	978525.91458	48	980891.02151	78	982993.51054
19	978580.19118	49	980980.90228	79	983029.01898
20	978636.95383	50	981070.35682	80	983061.58824
21	978696.13407	51	981159.27595	81	983091.17815
22	978757.66052	52	981247.55104	82	983117.75221
23	978821.45895	53	981335.07423	83	983141.27763
24	978887.45237	54	981421.73853	84	983161.78537
25	978955.56108	55	981507.43794	85	983179.07021
26	979025.70285	56	981592.06760	86	983193.29073
27	979097.79292	57	981675.52392	87	983204.36939
28	979171.74416	58	981757.70469	88	983212.29249
29	979247.46717	59	981838.50923	89	983217.05027
30	979324.87035	60	981917.83850	90	983218.63685

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SECTION 4

WGS 84

EARTH GRAVITATIONAL MODEL

Table 4.1

Form of the WGS 84
Earth Gravitational Model

$$V = \frac{GM}{r}\left[1 + \sum_{n=2}^{n_{max}} \sum_{m=0}^{n} \left(\frac{a}{r}\right)^n \overline{P}_{n,m}(\sin\phi')\left(\overline{C}_{n,m}\cos m\lambda + \overline{S}_{n,m}\sin m\lambda\right)\right]$$

Parameter	Definition
V	= Gravitational potential function
GM	= Earth's gravitational constant
r	= Radius vector from the earth's center of mass
a	= Semimajor axis of the WGS 84 Ellipsoid
n,m	= Degree and order, respectively
ϕ'	= Geocentric latitude
λ	= Geocentric longitude = geodetic longitude
$\overline{C}_{n,m}, \overline{S}_{n,m}$	= Normalized gravitational coefficients*
$\overline{P}_{n,m}(\sin\phi')$	= Normalized associated Legendre function
	$= \left[\frac{(n-m)!\ (2n+1)k}{(n+m)!}\right]^{1/2} P_{n,m}(\sin\phi')$
$P_{n,m}(\sin\phi')$	= Associated Legendre function

* See next page.

Table 4.1 (Cont'd)

Form of the WGS 84
Earth Gravitational Model

Parameter	Definition
$P_{n,m}(\sin\phi')$	$= (\cos\phi')^m \dfrac{d^m}{d(\sin\phi')^m}[P_n(\sin\phi')]$
$P_n(\sin\phi')$	= Legendre polynomial
$P_n(\sin\phi')$	$= \dfrac{1}{2^n n!}\dfrac{d^n}{d(\sin\phi')^n}(\sin^2\phi' - 1)^n$

*Note:

$$\begin{matrix}\bar{C}_{n,m} \\ \bar{S}_{n,m}\end{matrix} = \left[\frac{(n+m)!}{(n-m)!\,(2n+1)k}\right]^{1/2} \begin{matrix}C_{n,m} \\ S_{n,m}\end{matrix}$$

where

$C_{n,m}, S_{n,m}$ = Conventional gravitational coefficients

$m=0,\ k=1;$

$m\neq 0,\ k=2.$

Table 4.2

WGS 84
Earth Gravitational Model
(Truncated at n=m=18)

Degree and Order		Normalized Gravitational Coefficients		Degree and Order		Normalized Gravitational Coefficients	
n	m	$\overline{C}_{n,m}$	$\overline{S}_{n,m}$	n	m	$\overline{C}_{n,m}$	$\overline{S}_{n,m}$
2	0	-0.48416685E-03		6	3	0.53370577E-07	0.61334720E-08
2	1	----------	----------	6	4	-0.88694856E-07	-0.47260945E-06
2	2	0.24395796E-05	-0.13979548E-05	6	5	-0.26818820E-06	-0.53491073E-06
3	0	0.95706390E-06		6	6	0.10237832E-07	-0.23741002E-06
3	1	0.20318729E-05	0.25085759E-06	7	0	0.85819217E-07	
3	2	0.90666113E-06	-0.62102428E-06	7	1	0.27905196E-06	0.94231346E-07
3	3	0.71770352E-06	0.14152388E-05	7	2	0.32873832E-06	0.88835092E-07
4	0	0.53699587E-06		7	3	0.24940240E-06	-0.21223369E-06
4	1	-0.53548044E-06	-0.47420394E-06	7	4	-0.27123034E-06	-0.12696607E-06
4	2	0.34797519E-06	0.65579158E-06	7	5	0.10246290E-08	0.17321672E-07
4	3	0.99172321E-06	-0.19912491E-06	7	6	-0.35843745E-06	0.15202633E-06
4	4	-0.18686124E-06	0.30953114E-06	7	7	-0.20991457E-08	0.22805664E-07
5	0	0.71092048E-07		8	0	0.42979835E-07	
5	1	-0.64185265E-07	-0.92492959E-07	8	1	0.18889342E-07	0.47856967E-07
5	2	0.65184984E-06	-0.32007416E-06	8	2	0.73553952E-07	0.47867693E-07
5	3	-0.44903639E-06	-0.21328272E-06	8	3	-0.12132459E-07	-0.83461853E-07
5	4	-0.29719055E-06	0.53213480E-07	8	4	-0.24208264E-06	0.71603924E-07
5	5	0.17523221E-06	-0.67059456E-06	8	5	-0.24966587E-07	0.87751047E-07
6	0	-0.15064821E-06		8	6	-0.65093424E-07	0.30904202E-06
6	1	-0.74180259E-07	0.32780040E-07	8	7	0.66323292E-07	0.74661766E-07
6	2	0.51824409E-07	-0.35866634E-06	8	8	-0.12372281E-06	0.12210258E-06

E-03 = X 10^{-3}; E-05 = X 10^{-5}; Etc.

Table 4.2 (Cont'd)

WGS 84
Earth Gravitational Model
(Truncated at n=m=18)

Degree and Order		Normalized Gravitational Coefficients		Degree and Order		Normalized Gravitational Coefficients	
n	m	$\bar{C}_{n,m}$	$\bar{S}_{n,m}$	n	m	$\bar{C}_{n,m}$	$\bar{S}_{n,m}$
9	0	0.33173231E-07		11	2	0.21716225E-07	-0.10224810E-06
9	1	0.14747969E-06	0.23894354E-07	11	3	-0.30023695E-07	-0.13422019E-06
9	2	0.22052093E-07	-0.26876665E-07	11	4	-0.30407161E-07	-0.69823333E-07
9	3	-0.16256047E-06	-0.85928431E-07	11	5	0.35104609E-07	0.49175170E-07
9	4	-0.17193827E-07	0.26077030E-07	11	6	-0.37911105E-08	0.36848522E-07
9	5	-0.16902791E-07	-0.50337365E-07	11	7	0.25774039E-08	-0.88658395E-07
9	6	0.65717910E-07	0.22275858E-06	11	8	-0.71396627E-08	0.23243077E-07
9	7	-0.11648016E-06	-0.97298769E-07	11	9	-0.30246313E-07	0.41776400E-07
9	8	0.18896045E-06	-0.31026222E-08	11	10	-0.53424279E-07	-0.18716766E-07
9	9	-0.48275744E-07	0.96381072E-07	11	11	0.47514858E-07	-0.70415796E-07
10	0	0.50931575E-07		12	0	0.34073235E-07	
10	1	0.88706517E-07	-0.12536457E-06	12	1	-0.60609926E-07	-0.38189082E-07
10	2	-0.82375203E-07	-0.38280049E-07	12	2	0.74200188E-08	0.24640620E-07
10	3	-0.13137371E-07	-0.15553732E-06	12	3	0.42149817E-07	0.32189594E-07
10	4	-0.87424319E-07	-0.79215732E-07	12	4	-0.64346831E-07	-0.25364931E-08
10	5	-0.53980821E-07	-0.46294947E-07	12	5	0.33126200E-07	-0.40658586E-09
10	6	-0.42371448E-07	-0.79680607E-07	12	6	0.86981502E-08	0.36711094E-07
10	7	0.83736045E-08	-0.25636582E-08	12	7	-0.16598048E-07	0.34475954E-07
10	8	0.41239589E-07	-0.92269095E-07	12	8	-0.26843700E-07	0.17838309E-07
10	9	0.12539514E-06	-0.37687117E-07	12	9	0.42293015E-07	0.27107811E-07
10	10	0.10124370E-06	-0.24874984E-07	12	10	-0.44237357E-08	0.30823394E-07
11	0	-0.58114696E-07		12	11	0.96462514E-08	-0.60711291E-08
11	1	0.95375839E-08	-0.22094828E-07	12	12	-0.30878714E-08	-0.10932316E-07

E-03 = X 10^{-3}; E-05 = X 10^{-5}; Etc.

Table 4.2 (Cont'd)

WGS 84
Earth Gravitational Model
(Truncated at n=m=18)

Degree and Order		Normalized Gravitational Coefficients		Degree and Order		Normalized Gravitational Coefficients	
n	m	$\bar{C}_{n,m}$	$\bar{S}_{n,m}$	n	m	$\bar{C}_{n,m}$	$\bar{S}_{n,m}$
13	0	0.48159534E-07		14	7	0.39355808E-07	-0.52187212E-08
13	1	-0.47921675E-07	0.34957177E-07	14	8	-0.31866053E-07	-0.16609601E-07
13	2	0.48705121E-07	-0.63933232E-07	14	9	0.30182993E-07	0.23942248E-07
13	3	-0.17219549E-07	0.82465794E-07	14	10	0.36008306E-07	-0.43924872E-09
13	4	-0.92616056E-08	-0.98249479E-09	14	11	0.16006347E-07	-0.40475033E-07
13	5	0.58545255E-07	0.66075856E-07	14	12	0.79810549E-08	-0.31068551E-07
13	6	-0.28548757E-07	-0.13018250E-07	14	13	0.33446421E-07	0.44622344E-07
13	7	0.10048687E-07	-0.12672050E-07	14	14	-0.52174166E-07	-0.48789452E-08
13	8	-0.12236037E-07	-0.11680475E-07	15	0	-0.55534001E-08	
13	9	0.25798630E-07	0.46771958E-07	15	1	0.77027909E-08	0.12667983E-07
13	10	0.42112066E-07	-0.35203559E-07	15	2	-0.13310361E-07	-0.25570239E-07
13	11	-0.44423472E-07	-0.63137559E-08	15	3	0.53469109E-07	0.21540830E-07
13	12	-0.31610688E-07	0.86378230E-07	15	4	-0.35485140E-07	-0.38325971E-08
13	13	-0.61019573E-07	0.68712423E-07	15	5	0.80670670E-08	0.95367405E-08
14	0	-0.25559279E-07		15	6	0.28835774E-07	-0.29584853E-07
14	1	-0.10581256E-07	0.22739082E-07	15	7	0.55297561E-07	0.12688881E-07
14	2	-0.32588467E-07	-0.45984585E-08	15	8	-0.26866012E-07	0.28508669E-07
14	3	0.33411750E-07	0.72271094E-08	15	9	0.15229368E-07	0.40242957E-07
14	4	0.34163340E-08	-0.23062568E-07	15	10	0.78226264E-08	0.16482104E-07
14	5	0.21777499E-07	-0.44340974E-08	15	11	-0.45323941E-08	0.16379211E-07
14	6	-0.23022045E-07	0.79137357E-08	15	12	-0.34310516E-07	0.13248557E-07

E-03 = X 10^{-3}; E-05 = X 10^{-5}; Etc.

Table 4.2 (Cont'd)

WGS 84
Earth Gravitational Model
(Truncated at n=m=18)

Degree and Order		Normalized Gravitational Coefficients		Degree and Order		Normalized Gravitational Coefficients	
n	m	$\overline{C}_{n,m}$	$\overline{S}_{n,m}$	n	m	$\overline{C}_{n,m}$	$\overline{S}_{n,m}$
15	13	-0.27865470E-07	-0.51124016E-08	17	0	0.27418160E-07	
15	14	0.58007239E-08	-0.24830947E-07	17	1	-0.17492372E-07	-0.29004434E-07
15	15	-0.18756974E-07	-0.53745848E-08	17	2	-0.24972136E-07	0.52345300E-08
16	0	0.96352958E-08		17	3	0.75958226E-08	0.13161951E-07
16	1	0.16657011E-07	0.32088971E-07	17	4	-0.35567936E-08	0.29108859E-07
16	2	-0.22051986E-07	0.26286204E-07	17	5	-0.16440517E-07	0.15666155E-07
16	3	-0.29514849E-07	-0.95827659E-08	17	6	-0.29053420E-08	-0.41239945E-07
16	4	0.37621131E-07	0.55477548E-07	17	7	0.30327591E-07	-0.54652615E-08
16	5	-0.10479239E-07	-0.27382338E-08	17	8	0.26828952E-07	-0.69634040E-08
16	6	0.97407454E-08	-0.43087957E-07	17	9	-0.74685923E-09	-0.31300568E-07
16	7	-0.12168169E-07	-0.56636996E-08	17	10	-0.10536220E-08	0.18628074E-07
16	8	-0.25034024E-07	0.22895737E-08	17	11	-0.13049234E-07	0.13662390E-07
16	9	-0.17908785E-07	-0.29938908E-07	17	12	0.32820228E-07	0.17654374E-07
16	10	-0.10129689E-07	0.12404473E-07	17	13	0.17049873E-07	0.19279770E-07
16	11	0.19053980E-07	-0.17354590E-08	17	14	-0.14027974E-07	0.11214602E-07
16	12	0.18888013E-07	0.46949615E-08	17	15	0.56624501E-08	0.56527252E-08
16	13	0.15158142E-07	-0.17410596E-09	17	16	-0.32153542E-07	0.33341657E-08
16	14	-0.19416172E-07	-0.38724225E-07	17	17	-0.37961677E-07	-0.17192537E-07
16	15	-0.14400649E-07	-0.33151819E-07	18	0	0.10196218E-07	
16	16	-0.40920912E-07	0.23449430E-08	18	1	0.85717760E-08	-0.32887288E-07

E-03 = X 10^{-3}; E-05 = X 10^{-5}; Etc.

Table 4.2 (Cont'd)

WGS 84
Earth Gravitational Model
(Truncated at n=m=18)

Degree and Order		Normalized Gravitational Coefficients		Degree and Order		Normalized Gravitational Coefficients	
n	m	$\bar{C}_{n,m}$	$\bar{S}_{n,m}$	n	m	$\bar{C}_{n,m}$	$\bar{S}_{n,m}$
18	2	0.11021506E-07	0.96877203E-08	18	11	-0.92784417E-08	0.11278314E-08
18	3	-0.78128408E-08	-0.16263649E-07	18	12	-0.29997564E-07	-0.13762992E-07
18	4	0.50107239E-07	-0.35094534E-08	18	13	-0.61616779E-08	-0.34022737E-07
18	5	-0.35408518E-08	0.26790491E-07	18	14	-0.77166667E-08	-0.13392253E-07
18	6	0.12489735E-07	-0.12526195E-07	18	15	-0.38973604E-07	-0.20668220E-07
18	7	0.14813821E-07	-0.18829836E-08	18	16	0.10273437E-07	0.69198054E-08
18	8	0.35285229E-07	0.13368789E-08	18	17	0.33491685E-08	0.54056479E-08
18	9	-0.24544444E-07	0.25745394E-07	18	18	0.11121796E-08	-0.94806182E-08
18	10	0.84106552E-09	-0.44929528E-08				

E-03 = X 10^{-3}; E-05 = X 10^{-5}; Etc.

Table 4.3

WGS 84 EGM
Gravity Anomaly Degree Variances (c_n)*

Degree	Degree Variances	Degree	Degree Variances	Degree	Degree Variances
2	7.6	41	2.8	80	2.3
3	33.9	42	2.7	81	2.6
4	19.2	43	2.4	82	2.8
5	21.0	44	2.8	83	2.7
6	19.4	45	2.7	84	2.4
7	19.3	46	2.7	85	2.2
8	10.9	47	3.1	86	2.7
9	11.5	48	2.5	87	2.4
10	9.7	49	2.5	88	2.2
11	6.4	50	2.8	89	2.0
12	2.6	51	2.8	90	2.0
13	7.4	52	2.6	91	2.3
14	3.2	53	3.1	92	2.0
15	3.4	54	2.8	93	2.2
16	3.9	55	3.0	94	2.0
17	3.6	56	3.0	95	1.8
18	3.6	57	3.0	96	2.0
19	3.3	58	2.6	97	1.9
20	3.1	59	3.0	98	2.1
21	3.2	60	2.6	99	1.7
22	3.6	61	2.5	100	1.8
23	2.7	62	2.9	101	1.7
24	2.6	63	2.5	102	2.1
25	2.9	64	2.7	103	2.3
26	2.4	65	2.1	104	1.8
27	1.9	66	2.6	105	1.8
28	2.4	67	2.5	106	1.7
29	2.4	68	2.6	107	1.8
30	2.8	69	2.9	108	1.9
31	2.9	70	2.3	109	2.0
32	4.1	71	2.3	110	2.0
33	3.4	72	2.7	111	1.7
34	5.0	73	2.4	112	1.6
35	4.4	74	2.6	113	1.8
36	3.6	75	2.2	114	1.6
37	3.4	76	2.3	115	1.9
38	2.8	77	2.3	116	1.7
39	3.5	78	2.4	117	1.7
40	3.6	79	2.2	118	1.6

Units = milligals^2

* See next page.

Table 4.3 (Cont'd)

WGS 84 EGM
Gravity Anomaly Degree Variances (c_n)*

Degree	Degree Variances	Degree	Degree Variances	Degree	Degree Variances
119	1.6	140	1.3	161	0.9
120	1.6	141	1.1	162	0.8
121	1.5	142	1.0	163	0.9
122	1.3	143	1.1	164	1.0
123	1.6	144	1.1	165	0.9
124	1.6	145	1.0	166	0.8
125	1.5	146	1.0	167	0.9
126	1.3	147	1.0	168	0.8
127	1.5	148	1.2	169	0.8
128	1.2	149	1.0	170	0.8
129	1.4	150	1.0	171	0.9
130	1.3	151	1.0	172	0.7
131	1.3	152	1.0	173	0.8
132	1.4	153	1.0	174	0.8
133	1.4	154	1.0	175	0.8
134	1.2	155	0.9	176	0.8
135	1.2	156	1.0	177	0.6
136	1.2	157	0.8	178	0.7
137	1.3	158	0.8	179	0.8
138	1.3	159	0.8	180	0.8
139	1.2	160	0.9		

*Formula for computing gravity anomaly degree variances (c_n):

$$c_n = \bar{\gamma}^2 (n-1)^2 \sum_{m=0}^{n} (\bar{C}_{n,m}^2 + \bar{S}_{n,m}^2)$$

c_n = Gravity anomaly degree variance in milligals^2 for degree n

$\bar{\gamma}$ = Average value of theoretical gravity

$\bar{\gamma}$ = 979764.46561 milligals (based on WGS 84 Ellipsoidal Gravity Formula)

$\bar{C}_{n,m}$, $\bar{S}_{n,m}$ = Normalized gravitational coefficients of degree n and order m

Table 4.4

Comments on the WGS 84
Earth Gravitational Model

The official WGS 84 Earth Gravitational Model (EGM) is complete through degree (n) and order (m) 180 and is comprised of 32755 gravitational coefficients. While such a model is needed for certain applications on the earth's surface and in near-earth space, it is not required and is impractical to apply for many applications. However:

1. The WGS 84 EGM through n=m=180 is to be used when calculating:

a. WGS 84 geoid heights via a spherical harmonic expansion.

b. WGS 84 gravity disturbance components (or deflection of the vertical components) via a spherical harmonic expansion.

c. WGS 84 1°x1° mean gravity anomalies via a spherical harmonic expansion.

Expansions to this degree and order (n=m=180), and higher, are needed to accurately model variations in the earth's gravitational field on or near the earth's surface.

2. The WGS 84 EGM through n=m=41, which reflects the contribution of ground-based satellite tracking data (as does the complete n=m=180 model), is more appropriate for satellite orbit calculation and prediction purposes. The use of higher degree and order models for such applications is not recommended at this time. However, for each satellite orbit class, DMA and other DoD users will need to conduct orbital analyses to ascertain the EGM truncation level that is "best" for the satellite involved, document results, coordinate recommendations (as necessary), and then use this particular truncated EGM for the satellite being analyzed.

Table 4.4 (Cont'd)

Comments on the WGS 84
Earth Gravitational Model

The WGS 84 EGM coefficients through n=m=41 were obtained from a weighted least squares solution of a normal equation matrix developed by combining individual normal equation matrices formed from Doppler satellite tracking data, satellite laser ranging data, surface gravity data, oceanic geoid heights deduced from satellite radar altimeter data, NAVSTAR Global Positioning System (GPS) data, and "lumped coefficients". The effect (contribution) of coefficients through n=m=41 was removed from a worldwide 1°x1° mean gravity anomaly field leaving a worldwide residual 1°x1° mean gravity anomaly field. The WGS 84 EGM coefficients from n=42, m=0 through n=m=180 were then determined independently via harmonic analysis using the residual field. The coefficients through n=m=41 from the weighted least squares solution and the coefficients above n=m=41 from the independent harmonic analysis comprise the n=m=180 WGS 84 EGM.

The WGS 84 EGM through n=m=180 is available on magnetic tape in normalized form. The WGS 84 EGM through n=m=41 is available on a separate magnetic tape in both normalized and conventional form. However, only the WGS 84 EGM through n=m=18 is provided in this report (in normalized form). Requesters with a need for a higher degree and order portion of the model should make their requirements known to the address provided in the PREFACE.

Accuracy values are not available for all the individual WGS 84 EGM coefficients. However, an error covariance matrix is available for those coefficients through n=m=41 determined from the weighted least squares solution. Requesters having a need for this error data should also forward their correspondence to the address provided in the PREFACE.

Table 4.4 (Cont'd)

Comments on the WGS 84
Earth Gravitational Model

SECURITY CLASSIFICATION

The WGS 84 EGM (n=m=180) is classified CONFIDENTIAL, with the exception that the portion of the model through n=m=18 is UNCLASSIFIED. However, the UNCLASSIFIED portion of the EGM is authorized for use only in two instances:

- When a situation or application requires the use of an UNCLASSIFIED EGM, thereby precluding use of the CLASSIFIED WGS 84 EGM.

- When satellite orbital analyses conducted under Statement 2., above, reveal that the WGS 84 EGM truncated at n=m=18 (or lower) provides results of acceptable accuracy.

Error values for the WGS 84 EGM coefficients above n=m=18 are classified CONFIDENTIAL.

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SECTION 5

WGS 84 GEOID

Table 5.1

The WGS 84 Geoid

General Definition
<u>Definition 1</u> - That particular equipotential surface of the earth that coincides with mean sea level over the oceans and extends hypothetically beneath all land surfaces. <u>Definition 2</u> - In a mathematical or geometric sense, the geoid is defined as so many meters above (+N) or below (-N) the ellipsoid.
Function/Purpose of the Geoid
. Represents the earth's mean sea level surface and also serves: - In land areas (if conventional leveling is not available) as the vertical datum or reference surface to which height-above-mean sea level values are referenced. - In ocean areas as the geodetic height of points on the ocean's surface. . Indicates how well the mathematical figure of the earth (the ellipsoid) fits the earth's mean sea level surface.
Formula Used to Compute WGS 84 Geoid Heights
$N = \frac{GM}{r\gamma} \left[\sum_{n=2}^{180} \sum_{m=0}^{n} \left(\frac{a}{r}\right)^n (\bar{C}_{n,m} \cos m\lambda + \bar{S}_{n,m} \sin m\lambda)\, \bar{P}_{n,m} (\sin \phi') \right]$ N = WGS 84 Geoid Height (calculated using a spherical harmonic expansion and WGS 84 EGM coefficients through n=m=180) γ = Value of theoretical gravity calculated using the WGS 84 Ellipsoidal Gravity Formula All other parameters in this formula are defined as in Table 4.1 for the WGS 84 Earth Gravitational Model. [To apply this formula, see Sections 6.2.1 and 6.2.2 of Reference 2.]

Table 5.2

WGS 84 Geoid Heights
(n=m=180, 10°x10° Grid, Units = Meters)

Latitude (Degrees)	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°
90°	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
80°	33	34	28	23	17	13	9	4	4	1	-2	-2	0	2	3	2	1	1
70°	51	43	29	20	12	5	-2	-10	-14	-12	-10	-14	-12	-6	-2	3	6	4
60°	47	41	21	18	14	7	-3	-22	-29	-32	-32	-26	-15	-2	13	17	19	6
50°	47	48	42	28	12	-10	-19	-33	-43	-42	-43	-29	-2	17	23	22	6	2
40°	52	48	35	40	33	-9	-28	-39	-48	-59	-50	-28	3	23	37	18	-1	-11
30°	36	28	29	17	12	-20	-15	-40	-33	-34	-34	-28	7	29	43	20	4	-6
20°	31	26	15	6	1	-29	-44	-61	-67	-59	-36	-11	21	39	49	39	22	10
10°	22	23	2	-3	-7	-36	-59	-90	-95	-63	-24	12	53	60	58	46	36	26
0°	18	12	-13	-9	-28	-49	-62	-89	-102	-63	-9	33	58	73	74	63	50	32
-10°	12	13	-2	-14	-25	-32	-38	-60	-75	-63	-26	0	35	52	68	76	64	52
-20°	17	23	21	8	-9	-10	-11	-20	-40	-47	-45	-25	5	23	45	58	57	63
-30°	22	27	34	29	14	15	15	7	-9	-25	-37	-39	-23	-14	15	33	34	45
-40°	18	26	31	33	39	41	30	24	13	-2	-20	-32	-33	-27	-14	-2	5	20
-50°	25	26	34	39	45	45	38	39	28	13	-1	-15	-22	-22	-18	-15	-14	-10
-60°	16	19	25	30	35	35	33	30	27	10	-2	-14	-23	-30	-33	-29	-35	-43
-70°	16	16	17	21	20	26	26	22	16	10	-1	-16	-29	-36	-46	-55	-54	-59
-80°	-4	-1	1	4	4	6	5	4	2	-6	-15	-24	-33	-40	-48	-50	-53	-52
-90°	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30

Longitude (Degrees)

Table 5.2 (Cont'd)

WGS 84 Geoid Heights
(n=m=180, 10°x10° Grid, Units = Meters)

Latitude (Degrees)	180°	190°	200°	210°	220°	230°	240°	250°	260°	270°	280°	290°	300°	310°	320°	330°	340°	350°
90°	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
80°	3	1	-2	-3	-3	-3	-1	3	1	5	9	11	19	27	31	34	33	34
70°	2	2	1	-1	-3	-7	-14	-24	-27	-25	-19	3	24	37	47	60	61	58
60°	2	9	17	10	13	1	-14	-30	-39	-46	-42	-21	6	29	49	65	60	57
50°	-8	8	8	1	-11	-19	-16	-18	-22	-35	-40	-26	-12	24	45	63	62	59
40°	-12	-10	-13	-20	-31	-34	-21	-16	-26	-34	-33	-35	-26	2	33	59	52	51
30°	-7	-5	-8	-15	-28	-40	-42	-29	-22	-26	-32	-51	-40	-17	17	31	34	44
20°	5	10	7	-7	-23	-39	-47	-34	-9	-10	-20	-45	-48	-32	-9	17	25	31
10°	13	12	11	2	-11	-28	-38	-29	-10	3	1	-11	-41	-42	-16	3	17	33
0°	22	16	17	13	1	-12	-23	-20	-14	-3	14	10	-15	-27	-18	3	12	20
-10°	36	22	11	6	-1	-8	-10	-8	-11	-9	1	32	4	-18	-13	-9	4	14
-20°	51	27	10	0	-9	-11	-5	-2	-3	-1	9	35	20	-5	-6	-5	0	13
-30°	46	22	5	-2	-8	-13	-10	-7	-4	1	9	32	16	4	-8	4	12	15
-40°	21	6	1	-7	-12	-12	-12	-10	-7	-1	8	23	15	-2	-6	6	21	24
-50°	-15	-18	-18	-16	-17	-15	-10	-10	-8	-2	6	14	13	3	3	10	20	27
-60°	-45	-43	-37	-32	-30	-26	-23	-22	-16	-10	-2	10	20	20	21	24	22	17
-70°	-61	-60	-61	-55	-49	-44	-38	-31	-25	-16	-6	1	4	5	4	2	6	12
-80°	-53	-54	-55	-52	-48	-42	-38	-38	-29	-26	-26	-24	-23	-21	-19	-16	-12	-8
-90°	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30	-30

Longitude (Degrees)

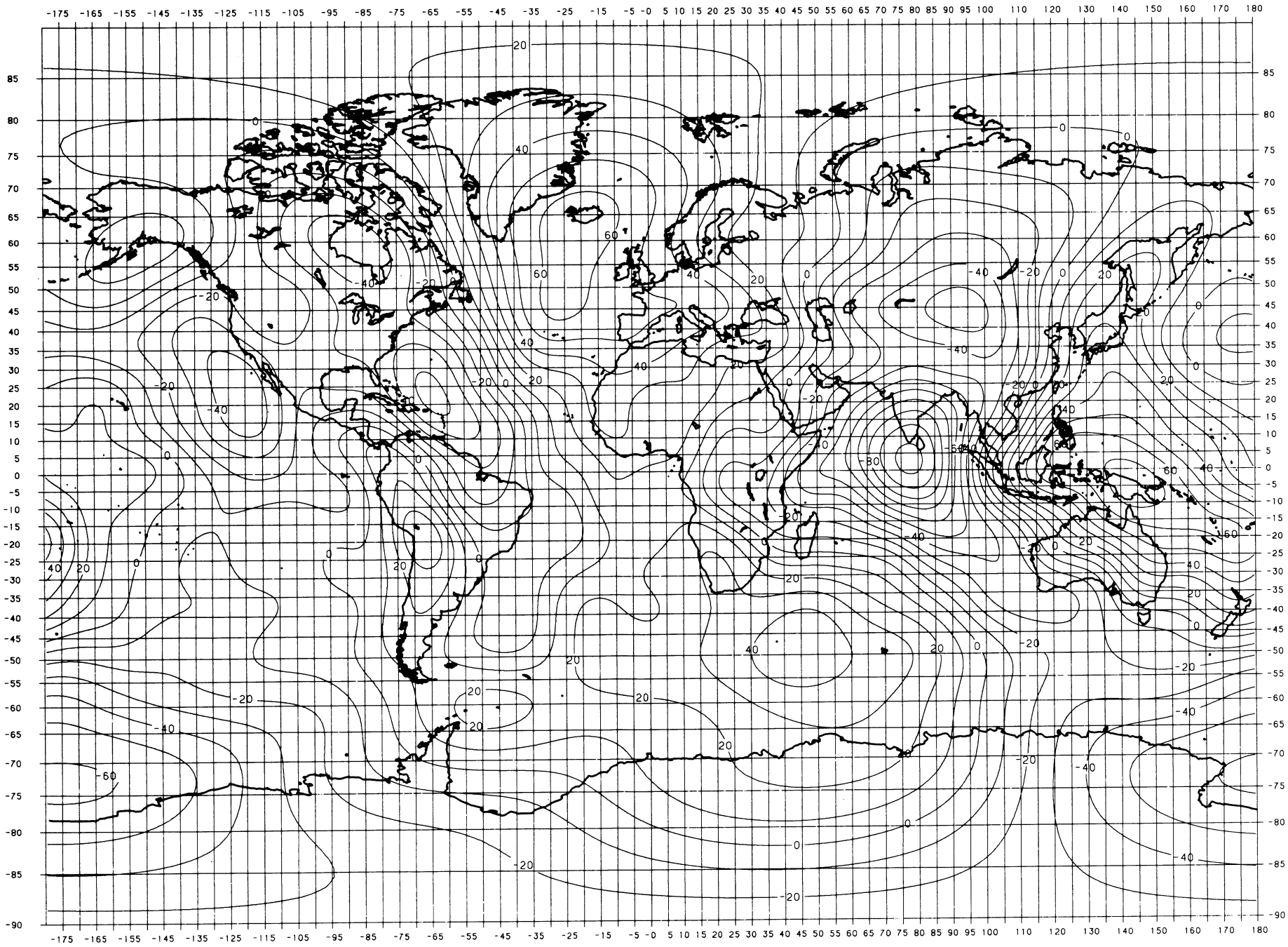

Figure 5.1. WGS 84 Geoid (n=m=18 Truncation) Referenced to WGS 84 Ellipsoid ($\overline{\delta C}_{4,0}$, $\overline{\delta C}_{6,0}$, $\overline{\delta C}_{8,0}$ and $\overline{\delta C}_{10,0} \neq 0$; Units = Meters)

Table 5.3

Interpolation of WGS 84 Geoid Heights

Bi-Linear Interpolation Method (Formula)
$N_P\ (\phi,\lambda) = a_0 + a_1X + a_2Y + a_3XY$
$N_P\ (\phi,\lambda)$ = Geoid height (N) to be interpolated at Point P (ϕ,λ)
$a_0 = N_1$
$a_1 = N_2 - N_1$
$a_2 = N_4 - N_1$
$a_3 = N_1 + N_3 - N_2 - N_4$
$X = (\lambda - \lambda_1)/(\lambda_2 - \lambda_1)$
$Y = (\phi - \phi_1)/(\phi_2 - \phi_1)$
ϕ = Geodetic latitude of Point P
λ = Geodetic longitude of Point P
N_1, N_2, N_3, N_4 = Known geoid heights at grid points used in the interpolation process
[See Associated Coordinate System, Figure 5.2]

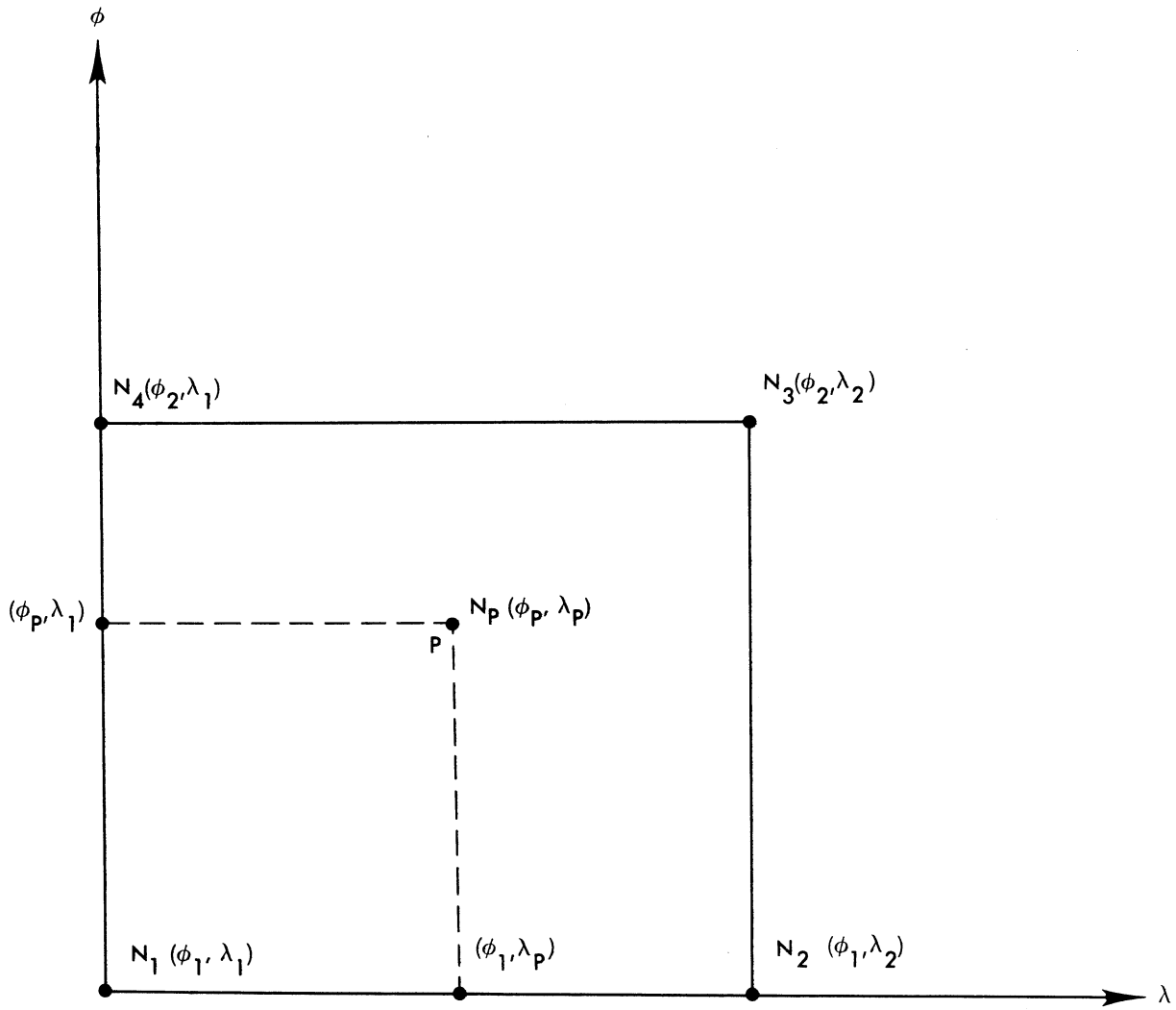

Figure 5.2. Coordinate System Associated With Geoid Height Bi-Linear Interpolation Scheme

Table 5-4

Comments on the WGS 84 Geoid

Geoid heights forming the WGS 84 Geoid were calculated using a spherical harmonic expansion and the WGS 84 EGM through n=m=180. The geodetic or gravimetric application involved dictates the geoid representation or product of most value to the user.

WGS 84 Geoid Height data and products that can be provided to requesters include:

1. A worldwide WGS 84 Geoid Height Contour Chart, contour interval = 5 meters. (See Reference 3.) If needed, contour charts of various physical size can be provided based on other contour intervals and scales, and for specific geographic areas.

2. A magnetic tape containing the worldwide 1°x1° grid of WGS 84 Geoid Heights used in developing the worldwide WGS 84 Geoid Height Contour Chart.

3. A magnetic tape containing a worldwide 30'x30' grid of WGS 84 Geoid Heights appropriate for use with the Bi-Linear Interpolation Method (Table 5.3; Figure 5.2) for interpolating WGS 84 Geoid Heights at random points. This interpolation scheme has an interpolation error (RMS difference) of ±0.09 meter based on a comparison between 259,200 calculated and interpolated WGS 84 Geoid Heights. Only 32 geoid height differences exceeded 1 meter, the largest difference being 1.55 meters. (See Reference 2.)

4. A computer program for calculating WGS 84 Geoid Heights at specified grid intervals or at random points. Associated documentation and appropriate test cases are an integral part of the computer program package.

Table 5.4 (Cont'd)

Comments on the WGS 84 Geoid

Requesters needing WGS 84 Geoid Height data and products not satisfied by either References 2 or 3 should make their requirements known to the address given in the PREFACE.

SECURITY CLASSIFICATION

A grid or database of WGS 84 Geoid Heights for a large geographic area, or for an aggregation of small areas equaling in size a large geographic area of continuous boundary, is classified CONFIDENTIAL. However, WGS 84 Geoid Heights are UNCLASSIFIED:

- When expressed in the form of a 10°x10° grid (Table 5.2), but only for a 10°x10° grid having those specific geodetic coordinates.

- At random points, except when CLASSIFIED on the basis of the site to which they refer.

- When calculated using the WGS 84 EGM truncated at $n=m\leq 18$ in a spherical harmonic expansion. (See Figure 5.1, for example.)

To avoid a possible security violation, users wishing to use WGS 84 Geoid Heights in an UNCLASSIFIED mode at random points or for small geographic areas should make their situation known to the address given in the PREFACE.

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SECTION 6

THREE METHODS FOR OBTAINING WGS 84 COORDINATES

The following three methods for obtaining WGS 84 coordinates are treated in this report:

- Local Geodetic System-to-WGS 84 Datum Transformations (Sections 6-23, 27)
- WGS 72-to-WGS 84 Transformation (Table 6.1, Sections 25-26, Table 27.1).
- Solving directly for WGS 84 coordinates using the Satellite Point Positioning technique and ground-based satellite tracking data acquired at (for) the site being positioned (Table 6.1, Section 24, Table 27.1)

Due to the various possibilities, accuracy levels, and complexities involved, Sections 6 through 27 should be carefully reviewed before a decision is made on the approach to use to obtain WGS 84 coordinates. A review of Chapters 7-9 of [2] is also recommended before making such a decision. Additional information may also be obtained through discussions with DMA personnel. (See address in PREFACE.)

NOTE 1: Although used in forming the mean datum shifts recorded in Table 10.1, Doppler station data for NAD 83 and Indian Datum (Bangladesh, India, and Nepal) were processed too late to permit preparation of many of the datum transformation graphics, etc., that are included in this report for other local geodetic systems. Requirements for such material may be made known to DMA. (See address in PREFACE.)

NOTE 2: Although, not always specifically stated, the term Western Europe includes the countries of Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland.

NOTE 3: The terms Ireland and Ireland Datum 1965 as used here, or in any of the related three volumes, pertain to the Republic of Ireland.

Table 6.1

Methods For Obtaining WGS 84 Coordinates
For
Sites of Interest

Data Situation at Sites to be Positioned on WGS 84	WGS 84 Positioning Method
1. Local geodetic system coordinates are available for the site, and perhaps WGS 72 coordinates. (No Doppler data and appropriate satellite ephemerides, or NSWC 9Z-2 coordinates, are available for the site.)	Use Local Geodetic System-to-WGS 84 Datum Transformation Formulas, ignoring any WGS 72 coordinates available.* (Use of a local geodetic system geodetic height that incorporates a DMA-developed local geoid height is needed to obtain a WGS 84 geodetic height of good quality.)
2. Only WGS 72 coordinates are available for the site. (No Doppler data and appropriate satellite ephemerides, or NSWC 9Z-2, or local geodetic system coordinates are available for the site.)	Re-positioning of the site via the next approach (below) is preferred since the WGS 72-to-WGS 84 Transformation does not reflect the effect of the WGS 84 Earth Gravitational Model and Geoid. However, Case 1 of the footnote is applicable here.
3. Ground-based satellite receivers have "tracked" NNSS satellites and acquired Doppler data at the site. (Local geodetic system coordinates may or may not be available for the site, and are not required.)	Use satellite point positioning and the Doppler data acquired at the site to solve for the site's coordinates directly in WGS 84. [The NNSS (satellite precise ephemerides, TRANET station coordinates, etc.) has been placed on WGS 84, in relevant software.] (See Section 24.)
NOTE: It is anticipated that situations will arise where both geocentric and relative positioning of many local sites to high accuracy on WGS 84 will be required. A weapon system test range is a good example of such a situation. When such situations arise, the preceding positioning procedures should not automatically be applied. Rather, the situation should first be reviewed to determine if a local area geodetic adjustment of all the sites on WGS 84 would be a more appropriate procedure. Defense Mapping Agency personnel are available for assisting in the performance of test range-related geodetic analyses and determining if any new surveys are required.	

* However, if the WGS 72 coordinates were determined from a satellite point positioning solution (Case 1), or from a Local Geodetic System-to-WGS 72 Datum Transformation utilizing localized datum shifts (Case 2), use of the WGS 72-to-WGS 84 Transformation (Table 25.2) will provide WGS 84 coordinates of good quality. (See Section 26 and Table 27.1 of this report and Sections 7.2.3 and 9.3. of Reference 2.)

Table 6.2
Techniques Available for Transforming
Local Geodetic System Coordinates (ϕ, λ, H) to WGS 84 Coordinates (ϕ, λ, H)

Options	Techniques
1	Standard Molodensky Datum Transformation Formulas and Localized ΔX, ΔY, ΔZ Datum Shifts (Interpolated from ΔX, ΔY, ΔZ Contour Charts).
2	Abridged Molodensky Datum Transformation Formulas and Localized ΔX, ΔY, ΔZ Datum Shifts (Interpolated from ΔX, ΔY, ΔZ Contour Charts).
3*	Datum Transformation Multiple Regression Equations.*
4	Interpolate $\Delta\phi$, $\Delta\lambda$, ΔH Values from $\Delta\phi$, $\Delta\lambda$, ΔH Contour Charts.
5	Standard Molodensky Datum Transformation Formulas with Regional ΔX, ΔY, ΔZ Datum Shifts.
6	Abridged Molodensky Datum Transformation Formulas with Regional ΔX, ΔY, ΔZ Datum Shifts.
7	Seven Parameter Datum Transformation Formulas ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$; ε, ψ, ω ; ΔS).
8	Six Parameter Datum Transformation Formulas ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$; ε, ψ, ω).
9	Four Parameter Datum Transformation Formulas ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$; ΔS).
10	Three Parameter Datum Transformation Formulas ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$).
11	Standard Molodensky Datum Transformation Formulas with Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$).
12	Abridged Molodensky Datum Transformation Formulas with Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$).
13	Coordinate Conversion (X, Y, Z to ϕ, λ, H ; See Section 7.2.4.3.4 of Reference 2.)

* This Technique for Calculating $\Delta\phi$, $\Delta\lambda$, ΔH Requires no Graphics or Interpolation Activities While Still Providing Good Accuracy.

Table 6.3

Advantages, Disadvantages, and/or Characteristics
of
Available Local Geodetic System-to-WGS 84 Datum Transformation Techniques

Datum Transformation Techniques	Advantages (and/or Characteristics)	Disadvantages (and/or Characteristics)
Standard Molodensky	. The most accurate of all the datum transformation techniques when localized datum shifts (ΔX, ΔY, ΔZ) are used. . Simple formulas; technique utilizes localized or mean datum shifts (translation parameters) and ellipsoid parameter differences (Δa, Δf). (When mean datum shifts are used, this technique is analogous to the three parameter datum transformation below.)	. Unless localized datum shifts (ΔX, ΔY, ΔZ) are used, this technique does not properly account for variable scale, survey errors, and distortions within the local geodetic network. However, some of the effect is reflected (absorbed) in the mean datum shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) . . Does not give the accuracy desired throughout the network when mean datum shifts are used unless the network is homogeneous (well-defined, well-adjusted).
Abridged Molodensky	. Formulas more simple than the Standard Molodensky; technique utilizes localized or mean datum shifts (translation parameters) and ellipsoid parameter differences (Δa, Δf).	. Slightly less accurate than the Standard Molodensky Formulas, and has the same disadvantages. (Due to the computational and storage capabilities available today, its use is no longer recommended.)
Multiple Regression Equations	. Technique that best accounts for variable scale, survey errors, and distortions within the local geodetic network, with the exception of the Standard and Abridged Molodensky Formulas when localized datum shifts are used. . Can be used throughout the local geodetic network and to the datum boundary if care has been used in determining the Multiple Regression Equation coefficients.	. Requires more terms than other datum transformation techniques if the local geodetic network is strongly non-homogeneous. . If inadvertently used external to area of derivation (representation), large errors are possible.

Table 6.3 (Cont'd)

Advantages, Disadvantages, and/or Characteristics
of
Available Local Geodetic System-to-WGS 84 Datum Transformation Techniques

Datum Transformation Techniques	Advantages (and/or Characteristics)	Disadvantages (and/or Characteristics)
Coordinate Conversion (X, Y, Z to ϕ, λ, H)	. Simple formulas; technique utilizes localized or mean datum shifts (translation parameters) and local geodetic system ellipsoid parameters (a, e^2).	. Has the same disadvantages as the Standard Molodensky Formulas; also has the disadvantage of being an iterative process with the attendant uncertainty regarding the number of iterations required to achieve convergence.
Seven Parameters	. Simple Formulas . Theoretically, a very correct technique since the formulas utilize least squares developed translation parameters ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$), rotation parameters (ε, ψ, ω), and a scale change parameter (ΔS).	. Does not achieve in practice its theoretical capability since it does not account for variable scale, survey errors, and distortions within the local geodetic network. However, the technique does determine and reflect mean scale and rotation parameters.
Six Parameters	. Simple Formulas . The formulas utilize least squares developed translation and rotation parameters ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$; ε, ψ, ω).	. Slightly less accurate than the seven parameter datum transformation.
Four Parameters	. Simple Formulas; [The formulas utilize least squares developed translation parameters ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) and a scale change parameter (ΔS)].	. Less accurate than the seven and six parameter datum transformations. . Does not give the accuracy desired throughout the network unless the network is homogeneous (well-defined, well-adjusted).

Table 6.3 (Cont'd)

Advantages, Disadvantages, and/or Characteristics
of
Available Local Geodetic System-to-WGS 84 Datum Transformation Techniques

Datum Transformation Techniques	Advantages (and/or Characteristics)	Disadvantages (and/or Characteristics)
Three Parameters	. Simple Formulas; [The formulas utilize least squares developed translation parameters ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$)].	. Less accurate than the seven and six parameter datum transformations. . Slightly less accurate than the four parameter datum transformation. . Does not give the accuracy desired throughout the network unless the network is homogeneous (well-defined, well-adjusted).

Table 6.4

Standard and Abridged Molodensky Datum Transformation Formulas
- Local Geodetic System to WGS 84 -

1. The Standard Molodensky Formulas

$$\Delta\phi'' = \{- \Delta X \sin\phi \cos\lambda - \Delta Y \sin\phi \sin\lambda + \Delta Z \cos\phi + \Delta a\,(R_N e^2 \sin\phi \cos\phi)/a + \Delta f\,[R_M(a/b) + R_N(b/a)] \sin\phi \cos\phi\} \cdot [(R_M + H) \sin 1'']^{-1}$$

$$\Delta\lambda'' = [- \Delta X \sin\lambda + \Delta Y \cos\lambda] \cdot [(R_N+H) \cos\phi \sin 1'']^{-1}$$

$$\Delta H_m = \Delta X \cos\phi \cos\lambda + \Delta Y \cos\phi \sin\lambda + \Delta Z \sin\phi - \Delta a\,(a/R_N) + \Delta f\,(b/a)\,R_N \sin^2\phi$$

2. The Abridged Molodensky Formulas

$$\Delta\phi'' = [-\Delta X \sin\phi \cos\lambda - \Delta Y \sin\phi \sin\lambda + \Delta Z \cos\phi + (a\Delta f + f\Delta a) \sin 2\phi] \cdot [R_M \sin 1'']^{-1}$$

$$\Delta\lambda'' = [-\Delta X \sin\lambda + \Delta Y \cos\lambda] \cdot [R_N \cos\phi \sin 1'']^{-1}$$

$$\Delta H_m = \Delta X \cos\phi \cos\lambda + \Delta Y \cos\phi \sin\lambda + \Delta Z \sin\phi + (a\Delta f + f\Delta a) \sin^2\phi - \Delta a$$

3. Definition of Terms in the Molodensky Formulas

ϕ, λ, H = geodetic coordinates (old ellipsoid)

ϕ = geodetic latitude. The angle between the plane of the geodetic equator and the ellipsoidal normal at a point (measured positive north from the geodetic equator, negative south).

λ = geodetic longitude. The angle between the plane of the Zero Meridian and the plane of the geodetic meridian of the point (measured in the plane of the geodetic equator, positive east from the Zero Meridian through 360°).

H = geodetic height (ellipsoidal height). The distance of a point from the ellipsoid measured from the surface of the ellipsoid along the ellipsoidal normal to the point.*

$H = N + h$

*This parameter does not appear in the Abridged Molodensky Formulas.

Table 6.4 (Cont'd)

Standard and Abridged Molodensky Datum Transformation Formulas
- Local Geodetic System to WGS 84 -

N = geoid/ellipsoid separation. The distance of the geoid above (+N) or below (-N) the ellipsoid. (Use of a DMA-developed local geoid height in forming a local geodetic system geodetic height is needed to obtain a WGS 84 geodetic height of good quality.)

*h = distance of a point from the geoid (elevation of the point above or below mean sea level); positive above mean sea level, negative below mean sea level.

$\Delta\phi$, $\Delta\lambda$, ΔH = corrections to transform local geodetic system coordinates to WGS 84 ϕ, λ, H values. The units of $\Delta\phi$ and $\Delta\lambda$ are arc seconds ("); the units of ΔH are meters (m).

ΔX, ΔY, ΔZ = shifts between centers of the local geodetic system and WGS 84 Ellipsoids; corrections to transform local geodetic system-related rectangular coordinates (X, Y, Z) to WGS 84-related X, Y, Z values.

a = semimajor axis of the local geodetic system ellipsoid.

*b = semiminor axis of the local geodetic system ellipsoid.

*b/a = 1 - f

f = flattening of the local geodetic system ellipsoid.

Δa, Δf = differences between the semimajor axis and flattening of the local geodetic system ellipsoid and the WGS 84 Ellipsoid, respectively.

e = first eccentricity.

$e^2 = 2f - f^2$

R_N = radius of curvature in the prime vertical.

$R_N = a/(1-e^2 \sin^2\phi)^{1/2}$

R_M = radius of curvature in the meridian.

$R_M = a(1-e^2)/(1-e^2 \sin^2 \phi)^{3/2}$

NOTE: All Δ-quantities are formed by subtracting local geodetic system ellipsoid values from WGS 84 Ellipsoid values.

* This parameter does not appear in the Abridged Molodensky Formulas.

Table 6.5

Differences Between Use Of Standard Versus Abridged Molodensky Datum Transformation Formulas In Determining WGS 84 Coordinates

Geodetic Coordinates	Maximum WGS 84 Coordinate Difference* as a Function of Height of Point Above Ellipsoid (H**)										
	H = 0	H = 2	H = 4	H = 6	H = 8	H = 10	H = 12	H = 14	H = 16	H = 18	H = 28
Latitude	0.59 m	0.59 m	0.59 m	0.62 m	0.71 m	0.86 m	1.02 m	1.17 m	1.33 m	1.45 m	2.22 m
Longitude	0.00	0.15	0.31	0.46	0.62	0.77	0.93	1.05	1.20	1.36	2.13
Height	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

* From Analysis Involving 21 Local Geodetic Systems

** H in Kilometers (e.g., H = 12 Kilometers is Approximately 40,000 Feet)

NOTE: Due to the computational and storage capabilities of today's calculators and computers, use of the Standard rather than the Abridged Molodensky Datum Transformation Formulas is recommended.

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SECTION 7

RECOMMENDED METHOD(S) FOR OBTAINING WGS 84 COORDINATES FROM LOCAL GEODETIC SYSTEM COORDINATES

Table 7.1

Recommended Method(s) for Obtaining WGS 84 Coordinates From Local Geodetic System Coordinates*

Situation	Recommended Coordinate Conversion Method
A relatively small number of local geodetic system coordinates need to be converted to WGS 84 coordinates, and the conversion can be accomplished in an office environment.	Estimate ΔX, ΔY, ΔZ Values from Local Geodetic System-to-WGS 84 Datum Shift Contour Charts and use them with the Standard Molodensky Datum Transformation Formulas to obtain $\Delta\phi$, $\Delta\lambda$, ΔH. To obtain accurate WGS 84 Geodetic Heights ($H_{WGS\ 84}$), estimate Local Geodetic System Geoid Heights (N_{DMA}) from the DMA-Developed Local Geodetic System Geoid Height Contour Charts and use in the Equation $H_{WGS\ 84} = (H_{Local} = N_{DMA} + h) + \Delta H$ where h = height above mean sea level.
A large number of local geodetic system coordinates needs to be converted to WGS 84 coordinates: - And/or the coordinate conversion needs to be acccomplished under field conditions. - And/or the coordinate conversion must be accomplished in near real time.	Program the Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH).** To obtain accurate WGS 84 Geodetic Heights ($H_{WGS\ 84}$), program the DMA-Developed Local Geodetic System Geoid Height Multiple Regression Equations for use with the Equation $H_{WGS\ 84} = (H_{Local} = N_{DMA} + h) + \Delta H$ where h = height above mean sea level.

* Also, See Tables 6.1 and 6.3, this Report, and Sections 7.2.4 and 7.4 of [2].

** CAUTION: Unacceptably large errors are possible unless use of these equations is rigorously restricted to within the boundary of their derivation (datum) area. For example, they should not be used in conjunction with a locally referenced map or chart (nautical, aeronautical) to obtain WGS 84 positions external to the land areas associated with the local geodetic system on which the map or chart is based.

Table 7.2

- Test Case 1 -

Conversion of Local Geodetic System Coordinates to WGS 84 Coordinates Using the Standard Molodensky Datum Transformation Formulas and ΔX, ΔY, ΔZ , N_{DMA} Values Estimated From Local Geodetic System-to-WGS 84 Datum Shift Contour Charts and DMA-Developed Local Geodetic System Geoid Height Contour Charts

1. Test Point Coordinates (NAD 27)

ϕ = 42°56'51.9"N

λ = 288°22'22.6"E

h = 232 m

[ϕ = Geodetic Latitude, λ = Geodetic Longitude, h = Height Above Mean Sea Level]

2. Values Estimated From Contour Charts (Figures 13.1, 13.2, 13.3, 17.1)

ΔX = -13 m; ΔY = 165 m; ΔZ = 185 m; N_{DMA} = 3 m (Clarke 1866 Ellipsoid)

Also, from Tables 8.2 and 8.3:

a = 6378206.4 f = 1/294.9786982

Δa = -69.4 m $\Delta f = -0.37264639 \times 10^{-4}$

3. Values Calculated Using Standard Molodensky Datum Transformation Formulas

$\Delta\phi$ = 0.247"; $\Delta\lambda$ = 1.750"; ΔH = -32.42 m

4. Coordinate Conversion Formulas and Results

$\phi_{WGS\ 84} = \phi_{NAD\ 27} + \Delta\phi =$ 42°56'52.147"N

$\lambda_{WGS\ 84} = \lambda_{NAD\ 27} + \Delta\lambda =$ 288°22'24.350"E

$H_{WGS\ 84} = (H_{Local} = N_{DMA} + h) + \Delta H$ = 202.58 m

Table 7.3

- Test Case 2 -

Conversion of Local Geodetic System Coordinates to WGS 84 Coordinates Using Local Geodetic System-to-WGS 84 Datum Shift Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH) and DMA-Developed Local Geodetic System Geoid Height Multiple Regression Equations

Local Geodetic System	Test Point Local Geodetic System Coordinates			Test Point Calculated WGS 84 Coordinates		
	Geodetic Latitude	Geodetic Longitude	Height Above MSL	Geodetic Latitude	Geodetic Longitude	Geodetic Height
NAD 27*	42°56'51.9" N	288°22'22.6" E	232 m	42°56'52.163" N	288°22'24.326" E	203.38 m
NAD 83*	---	---	--	---	---	--
SAD 69	06 30 23.1 N	301 44 20.9 E	27	06 30 21.647 N	301 44 19.541 E	-1.48
ED 50 (Western Europe)	49 24 11.2 N	07 32 04.3 E	360	49 24 08.173 N	07 32 00.137 E	407.44
ED 50 (UK/Ireland)	58 33 06.6 N	-03 14 18.5 W	51	58 33 04.168 N	-03 14 24.674 W	102.36
ED 50 (UK Only)	50 52 05.7 N	00 20 25.2 E	12	50 52 02.566 N	00 20 20.250 E	55.94
TD	35 10 50.4 N	129 07 13.8 E	4	35 11 01.563 N	129 07 05.702 E	33.46
AGD 66	-20 38 00.6 S	144 24 29.4 E	515	-20 37 55.121 S	144 24 33.423 E	565.50
AGD 84	-25 06 54.9 S	113 43 48.8 E	13	-25 06 50.343 S	113 43 53.762 E	-8.13

MSL = Mean Sea Level

* Contiguous United States (CONUS); (NAD 83-to-WGS 84 Datum Shift Multiple Regression Equations Were Not Developed Due to the Good Agreement Between NAD 83 and WGS 84 Coordinates.)

SECTION 8

LOCAL GEODETIC SYSTEMS RELATED TO WGS 84, ASSOCIATED REFERENCE ELLIPSOIDS (THEIR PARAMETERS AND PARAMETER DIFFERENCES), THE GEOGRAPHIC LOCATION OF LOCAL GEODETIC SYSTEMS, AND ENUMERATION OF PRODUCTS FOR ACCOMPLISHING THEIR TRANSFORMATION TO WGS 84

Table 8.1

Local Geodetic Systems
Related to World Geodetic System 1984

Local Geodetic Systems (Datums)	Associated Reference Ellipsoid
Adindan	Clarke 1880
Afgooye	Krassovsky
Ain el Abd 1970	International
Anna 1 Astro 1965	Australian National
Arc 1950	Clarke 1880
Arc 1960	Clarke 1880
Ascension Island 1958	International
Astro Beacon "E"	International
Astro B4 Sorol Atoll	International
Astro DOS 71/4	International
Astronomic Station 1952	International
Australian Geodetic 1966	Australian National
Australian Geodetic 1984	Australian National
Bellevue (IGN)	International
Bermuda 1957	Clarke 1866
Bogota Observatory	International
Campo Inchauspe	International
Canton Astro 1966	International
Cape	Clarke 1880
Cape Canaveral	Clarke 1866
Carthage	Clarke 1880
Chatham 1971	International
Chua Astro	International
Corrego Alegre	International
Djakarta	Bessel 1841
DOS 1968	International
Easter Island 1967	International
European 1950	International
European 1979	International
Gandajika Base	International
Geodetic Datum 1949	International
Guam 1963	Clarke 1866
GUX 1 Astro	International
Hjorsey 1955	International
Hong Kong 1963	International
Indian	Everest
Ireland 1965	Modified Airy
ISTS 073 Astro 1969	International
Johnston Island 1961	International
Kandawala	Everest
Kerguelen Island	International
Kertau 1948	Modified Everest

Table 8.1 (Cont'd)

Local Geodetic Systems
Related to World Geodetic System 1984

Local Geodetic Systems (Datums)	Associated Reference Ellipsoid
L. C. 5 Astro	Clarke 1866
Liberia 1964	Clarke 1880
Luzon	Clarke 1866
Mahe 1971	Clarke 1880
Marco Astro	International
Massawa	Bessel 1841
Merchich	Clarke 1880
Midway Astro 1961	International
Minna	Clarke 1880
Nahrwan	Clarke 1880
Naparima, BWI	International
North American 1927	Clarke 1866
North American 1983	GRS 80*
Observatorio 1966	International
Old Egyptian	Helmert 1906
Old Hawaiian	Clarke 1866
Oman	Clarke 1880
Ordnance Survey of Great Britain 1936	Airy
Pico de las Nieves	International
Pitcairn Astro 1967	International
Provisional South Chilean 1963**	International
Provisional South American 1956	International
Puerto Rico	Clarke 1866
Qatar National	International
Qornoq	International
Reunion	International
Rome 1940	International
Santo (DOS)	International
São Braz	International
Sapper Hill 1943	International
Schwarzeck	Bessel 1841
South American 1969	South American 1969
South Asia	Modified Fischer 1960
Southeast Base	International
Southwest Base	International
Timbalai 1948	Everest
Tokyo	Bessel 1841
Tristan Astro 1968	International
Viti Levu 1916	Clarke 1880
Wake-Eniwetok 1960	Hough
Zanderij	International

* Geodetic Reference System 1980
** Also known as Hito XVIII 1963

Table 8.2

Reference Ellipsoid Constants

Reference Ellipsoids	a (Meters)	f
Airy	6377563.396	1/299.3249646
Modified Airy	6377340.189	1/299.3249646
Australian National	6378160	1/298.25
Bessel 1841	6377397.155*	1/299.1528128
Clarke 1866	6378206.4	1/294.9786982
Clarke 1880	6378249.145	1/293.465
Everest	6377276.345	1/300.8017
Modified Everest	6377304.063	1/300.8017
Fischer 1960 (Mercury)	6378166	1/298.3
Modified Fischer 1960 (South Asia)	6378155	1/298.3
Fischer 1968	6378150	1/298.3
Geodetic Reference System 1967	6378160	1/298.247167427
Geodetic Reference System 1980	6378137	1/298.257222101
Helmert 1906	6378200	1/298.3
Hough	6378270	1/297
International	6378388	1/297
Krassovsky	6378245	1/298.3
South American 1969	6378160	1/298.25
WGS 60	6378165	1/298.3
WGS 66	6378145	1/298.25
WGS 72	6378135	1/298.26
WGS 84	6378137	1/298.257223563

* In Namibia, use a = 6377483.865 meters for the Bessel 1841 Ellipsoid.

Table 8.3

Difference in Ellipsoid Size (Δa) and Shape (Δf)
- WGS 84 Minus Other Reference Ellipsoids -

Reference Ellipsoids	Δa (m)	$\Delta f \times 10^4$
Airy	573.604	0.11960023
Modified Airy	796.811	0.11960023
Australian National	-23	-0.00081204
Bessel 1841	739.845*	0.10037483
Clarke 1866	-69.4	-0.37264639
Clarke 1880	-112.145	-0.54750714
Everest	860.655	0.28361368
Modified Everest	832.937	0.28361368
Fischer 1960 (Mercury)	-29	0.00480795
Modified Fischer 1960 (South Asia)	-18	0.00480795
Fischer 1968	-13	0.00480795
Geodetic Reference System 1967	-23	-0.00113048
Geodetic Reference System 1980	0	-0.00000016
Helmert 1906	-63	0.00480795
Hough	-133	-0.14192702
International	-251	-0.14192702
Krassovsky	-108	0.00480795
South American 1969	-23	-0.00081204
WGS 60	-28	0.00480795
WGS 66	-8	-0.00081204
WGS 72	2	0.0003121057**

* In Namibia, use Δa = 653.135 meters. (This reflects a semimajor axis of a = 6377483.865 meters for the Bessel 1841 Ellipsoid in Namibia.)
** Consistency maintained with Table 2.5.

Table 8.4

Reference Ellipsoid Constants (b, e^2)

Reference Ellipsoids	b (Meters)	e^2
Airy	6356256.909	0.006670540000
Modified Airy	6356034.448	0.006670540000
Australian National	6356774.719	0.006694541855
Bessel 1841	6356078.963*	0.006674372232
Clarke 1866	6356583.8	0.006768657998
Clarke 1880	6356514.870	0.006803511283
Everest	6356075.413	0.006637846630
Modified Everest	6356103.039	0.006637846630
Fischer 1960 (Mercury)	6356784.284	0.006693421623
Modified Fischer 1960 (South Asia)	6356773.320	0.006693421623
Fischer 1968	6356768.337	0.006693421623
Geodetic Reference System 1967	6356774.516	0.006694605329
Geodetic Reference System 1980	6356752.3141	0.00669438002290
Helmert 1906	6356818.170	0.006693421623
Hough	6356794.343	0.006722670022
International	6356911.946	0.006722670022
Krassovsky	6356863.019	0.006693421623
South American 1969	6356774.719	0.006694541855
WGS 60	6356783.287	0.006693421623
WGS 66	6356759.769	0.006694541855
WGS 72	6356750.520	0.006694317778
WGS 84	6356752.3142	0.00669437999013

* In Namibia, use b = 6356165.383 meters for the Bessel 1841 Ellipsoid.

Table 8.5

Page Number of Products For Accomplishing
Local Geodetic System-to-WGS 84 Datum Transformations

Local Geodetic Systems (Datums)	Mean ΔX, ΔY, ΔZ Datum Shifts	Contour Charts			Multiple Regression Equations	
		ΔX, ΔY, ΔZ Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights	Δφ, Δλ, ΔH Datum Shifts	Δφ, Δλ, ΔH Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights
1. Adindan	10-2	*14-2, 3, 4	*18-2	*16-2, 3, 4	20-2, 49	23-2, 44
2. Afgooye	10-2				20-49	23-44
3. Ain el Abd 1970	10-2				20-49	23-44
4. Anna 1 Astro 1965	10-2				20-49	23-44
5. Arc 1950	10-3	14-5, 6, 7	18-3	16-5, 6, 7	20-3	23-3
6. Arc 1960	10-4	14-8, 9, 10	18-4	16-8, 9, 10	20-4	23-4
7. Ascension Island 1958	10-4				20-49	23-44
8. Astro Beacon "E"	10-4				20-49	23-44
9. Astro B4 Sorol Atoll	10-4				20-49	23-44
10. Astro DOS 71/4	10-4				20-49	23-44
11. Astronomic Station 1952	10-4				20-50	23-44
12. Australian Geodetic 1966	9-1, 10-5	13-23, 24, 25	17-9	15-23, 24, 25	19-12, 13	22-8
13. Australian Geodetic 1984	9-1, 10-5	13-26, 27, 28	17-10	15-26, 27, 28	19-14, 15	22-9
14. Bellevue (IGN)	10-5				20-5	23-44
15. Bermuda 1957	10-5				20-6	23-44
16. Bogota Observatory	10-5	14-11, 12, 13	18-5	16-11, 12, 13	20-7	23-5
17. Campo Inchauspe	10-5	14-14, 15, 16	18-6	16-14, 15, 16	20-8	23-6
18. Canton Astro 1966	10-6				20-9	23-7
19. Cape	10-6	14-17, 18, 19	18-7	16-17, 18, 19	20-10	23-8
20. Cape Canaveral	10-6	14-20, 21, 22	18-8	16-20, 21, 22	20-11	23-9
21. Carthage	10-6	14-23, 24, 25	18-9	16-23, 24, 25	20-12	23-10
22. Chatham 1971	10-6				20-13	23-44
23. Chua Astro	10-6	14-26, 27, 28	18-10	16-26, 27, 28	20-14	23-11
24. Corrego Alegre	10-6	14-29, 30, 31	18-11	16-29, 30, 31	20-15	23-12
25. Djakarta	10-7	14-32, 33, 34	18-12	16-32, 33, 34	20-16	23-13
26. DOS 1968	10-7				20-50	23-44
27. Easter Island 1967	10-7				20-50	23-44

* Ethiopia and Sudan Only

Table 8.5 (Cont'd)

Page Number of Products For Accomplishing
Local Geodetic System-to-WGS 84 Datum Transformations

Local Geodetic Systems (Datums)	Mean ΔX, ΔY, ΔZ Datum Shifts	Contour Charts			Multiple Regression Equations	
		ΔX, ΔY, ΔZ Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights	Δφ, Δλ, ΔH Datum Shifts	Δφ, Δλ, ΔH Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights
28. European 1950						
. Western Europe	9-1, 10-7	13-11, 12, 13	17-5	15-11, 12, 13	19-6, 7	22-4
. Western Europe (Limited)	10-8				19-6, 7	22-4
. UK/Ireland	9-1, 10-8	13-14, 15, 16	17-6	15-14, 15, 16	19-8	22-5
. UK Only	9-1, 10-8	13-17, 18, 19	17-7	15-17, 18, 19	19-9	22-6
. Cyprus	10-8				20-17	23-14
. Egypt	10-8	14-35, 36, 37	18-13	16-35, 36, 37	20-18	23-15
. Greece	10-8				19-6, 7	22-4
. Iran	10-8	14-38, 39, 40	18-14	16-38, 39, 40	20-19	23-16
. Italy (Sardinia, Sicily)	10-8				20-50	23-44
. Norway and Finland	10-8				19-6, 7	22-4
. Portugal and Spain	10-9				19-6, 7	22-4
29. European 1979	10-9					
30. Gandajika Base	10-9				20-50	23-44
31. Geodetic Datum 1949	10-9	14-41, 42, 43	18-15	16-41, 42, 43	20-20	23-17
32. Guam 1963	10-9				20-21	23-18
33. GUX 1 Astro	10-9				20-50	23-45
34. Hjorsey 1955	10-9	14-44, 45, 46	18-16	16-44, 45, 46	20-22	23-19
35. Hong Kong 1963	10-10				20-50	23-45
36. Indian	10-10	**14-47, 48, 49	**18-17	**16-47, 48, 49	20-23, 50	23-20, 45
37. Ireland 1965	10-10	14-50, 51, 52	18-18	16-50, 51, 52	20-24	23-21
38. ISTS 073 Astro 1969	10-10				20-51	23-45
39. Johnston Island 1961	10-10				20-51	23-45
40. Kandawala	10-10				20-25	23-22
41. Kerguelen Island	10-10				20-51	23-45
42. Kertau 1948	10-10	14-53, 54, 55	18-19	16-53, 54, 55	20-26	23-23

** Thailand and Vietnam only.

Table 8.5 (Cont'd)

Page Number of Products For Accomplishing
Local Geodetic System-to-WGS 84 Datum Transformations

Local Geodetic Systems (Datums)	Mean ΔX, ΔY, ΔZ Datum Shifts	Contour Charts			Multiple Regression Equations	
		ΔX, ΔY, ΔZ Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights	Δφ, Δλ, ΔH Datum Shifts	Δφ, Δλ, ΔH Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights
43. L.C. 5 Astro	10-11				20-51	23-45
44. Liberia 1964	10-11				20-27	23-24
45. Luzon	10-11	14-56, 57, 58	18-20	16-56, 57, 58	20-28, 51	23-25, 45
46. Mahe 1971	10-11				20-51	23-45
47. Marco Astro	10-11				20-51	23-45
48. Massawa	10-12				20-51	23-45
49. Merchich	10-12	14-59, 60, 61	18-21	16-59, 60, 61	20-29	23-26
50. Midway Astro 1961	10-12				20-52	23-45
51. Minna	10-12	14-62, 63, 64	18-22	16-62, 63, 64	20-30	23-27
52. Nahrwan	10-12				20-31, 52	23-28, 45
53. Naparima, BWI	10-13				20-52	23-45
54. North American 1927						
. Alaska	10-14	14-65, 66, 67	18-23	16-65, 66, 67	20-32	23-29
. Canada	10-15	14-68, 69, 70	18-24	16-68, 69, 70	20-33, 34	23-30
. Greenland/Hayes Peninsula	10-16		18-26		20-52	23-45
. CONUS	9-1, 10-13	13-2, 3, 4	17-2	15-2, 3, 4	19-2, 3	22-2
. Eastern CONUS	10-13, 14					
. Western CONUS	10-13					
. Mexico	10-17				20-36	23-32
. Mexico, Central America		14-74, 75, 76	18-27	16-74, 75, 76	20-36	23-32
. Central America	10-16				20-36	23-32
. Canal Zone	10-16	14-74, 75, 76	18-27	16-74, 75, 76	20-36	23-32
. Caribbean	10-16	14-71, 72, 73	18-25	16-71, 72, 73	20-35	23-31
. Cuba	10-16	14-71, 72, 73	18-25	16-71, 72, 73	20-35	23-31
. Bahamas [Excluding San Salvador Island]	10-14	14-71, 72, 73	18-25	16-71, 72, 73	20-35	23-31
. San Salvador Island	10-14	14-71, 72, 73	18-25	16-71, 72, 73	20-35	23-31

Table 8.5 (Cont'd)

Page Number of Products For Accomplishing
Local Geodetic System-to-WGS 84 Datum Transformations

Local Geodetic Systems (Datums)	Mean ΔX, ΔY, ΔZ Datum Shifts	Contour Charts			Multiple Regression Equations	
		ΔX, ΔY, ΔZ Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights	Δφ, Δλ, ΔH Datum Shifts	Δφ, Δλ, ΔH Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights
55. North American 1983***						
. Alaska	10-17					
. Canada	10-17					
. CONUS	9-1, 10-17	13-5, 6, 7	17-3	15-5, 6, 7		
. Mexico, Central America	10-17					
56. Observatorio 1966	10-17				20-52	23-45
57. Old Egyptian	10-17	14-77, 78, 79	18-28	16-77, 78, 79	20-37	23-33
58. Old Hawaiian	10-18	14-80, 81, 82	18-29	16-80, 81, 82	20-38	23-34
59. Oman	10-18	14-83, 84, 85	18-30	16-83, 84, 85	20-39	23-35
60. Ordnance Survey of Great Britain 1936	10-18, 19	14-86, 87, 88	18-31	16-86, 87, 88	20-40	23-36
61. Pico de las Nieves	10-19				20-52	23-46
62. Pitcairn Astro 1967	10-19				20-52	23-46
63. Provisional South Chilean 1963	10-19				20-52	23-46
64. Provisional South American 1956	10-20, 21	14-89, 90, 91	18-32	16-89, 90, 91	20-41, 42	23-37
65. Puerto Rico	10-21	14-92, 93, 94	18-33	16-92, 93, 94	20-43	23-38
66. Qatar National	10-21				20-44	23-39
67. Qornoq	10-21		18-34		20-52	23-46
68. Reunion	10-21				20-53	23-46
69. Rome 1940	10-21				20-53	23-46
70. Santo (DOS)	10-22				20-53	23-46
71. São Braz	10-22				20-53	23-46
72. Sapper Hill 1943	10-22				20-53	23-46
73. Schwarzeck	10-22				20-53	23-46
74. South American 1969	9-1, 10-22	13-8, 9, 10	17-4	15-8, 9, 10	19-4, 5	22-3
. Argentina	10-23					
. Bolivia	10-23					

*** Time constraints prevented inclusion of contour charts (ΔX, ΔY, ΔZ; Δφ, Δλ, ΔH; DMA-developed local geodetic system geoid heights) for NAD 83 (Alaska, Canada, and Mexico, Central America). If such data is required, contact DMA (see PREFACE).

Table 8.5 (Cont'd)

Page Number of Products For Accomplishing
Local Geodetic System-to-WGS 84 Datum Transformations

Local Geodetic Systems (Datums)	Mean ΔX, ΔY, ΔZ Datum Shifts	Contour Charts			Multiple Regression Equations	
		ΔX, ΔY, ΔZ Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights	Δφ, Δλ, ΔH Datum Shifts	Δφ, Δλ, ΔH Datum Shifts	DMA-Developed Local Geodetic System Geoid Heights
South American 1969 (Cont'd)						
. Brazil	10-23					
. Chile	10-23					
. Colombia	10-23					
. Ecuador	10-23					
. Guyana	10-23					
. Paraguay	10-23					
. Peru	10-23					
. Trinidad and Tobago	10-24					
. Venezuela	10-24					
75. South Asia	10-24				20-53	23-46
76. Southeast Base	10-24				20-53	23-46
77. Southwest Base	10-25	14-95, 96, 97	18-35	16-95, 96, 97	20-45	23-40
78. Timbalai 1948	10-25	14-98, 99, 100	18-36	16-98, 99, 100	20-46	23-41
79. Tokyo	9-1, 10-25				19-10, 11	22-7
. Japan	10-25	13-20, 21, 22	17-8	15-20, 21, 22		
. Korea	10-25	13-20, 21, 22	17-8	15-20, 21, 22		
. Okinawa	10-25					
80. Tristan Astro 1968	10-26				20-53	23-46
81. Viti Levu 1916	10-26				20-53	23-46
82. Wake-Eniwetok 1960	10-26	14-101, 102, 103	18-37	16-101, 102, 103	20-47	23-42
83. Zanderij	10-26	14-104, 105, 106	18-38	16-104, 105, 106	20-48	23-43

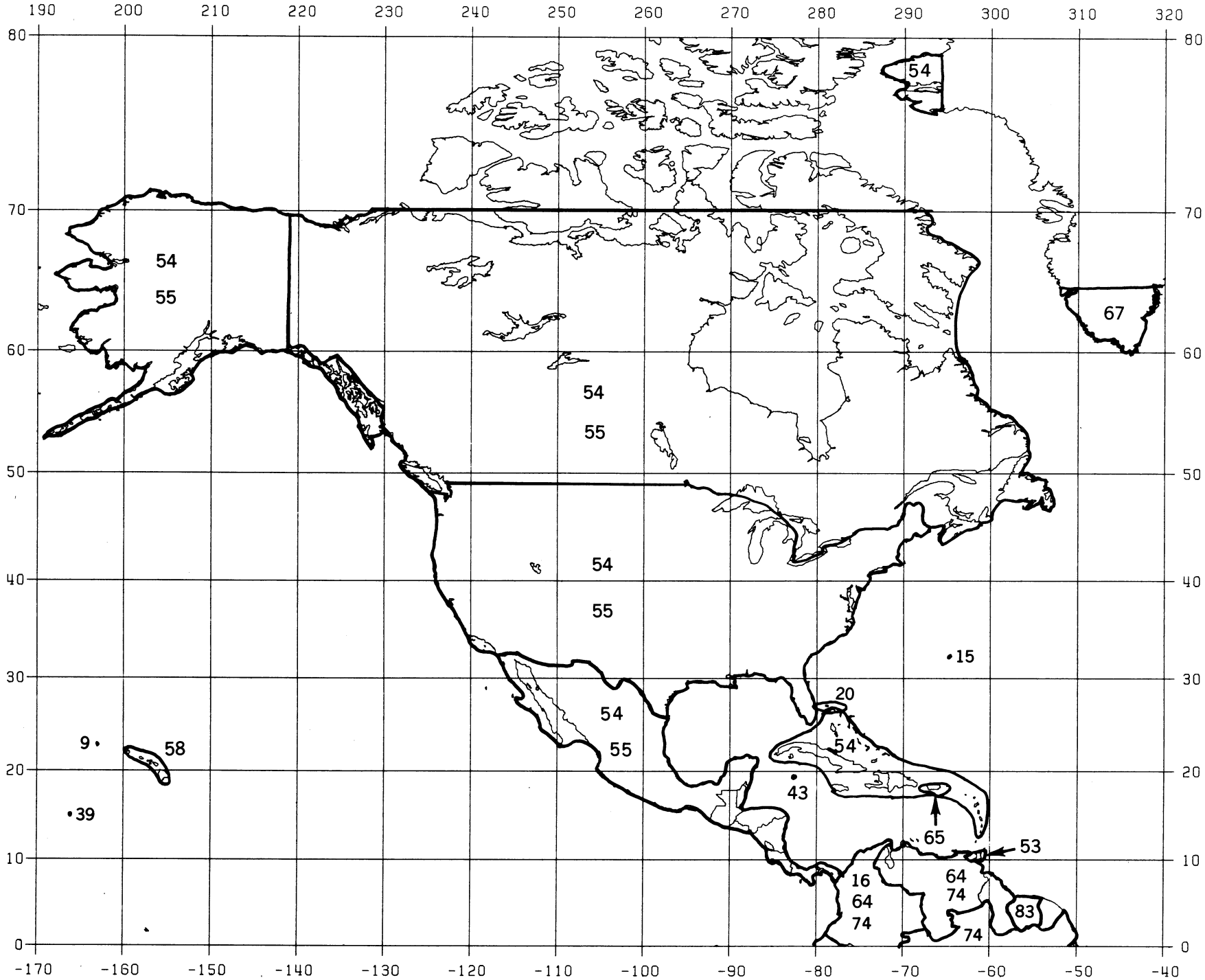

Figure 8.1a. Local Geodetic Systems (Table 8.5) Related to WGS 84

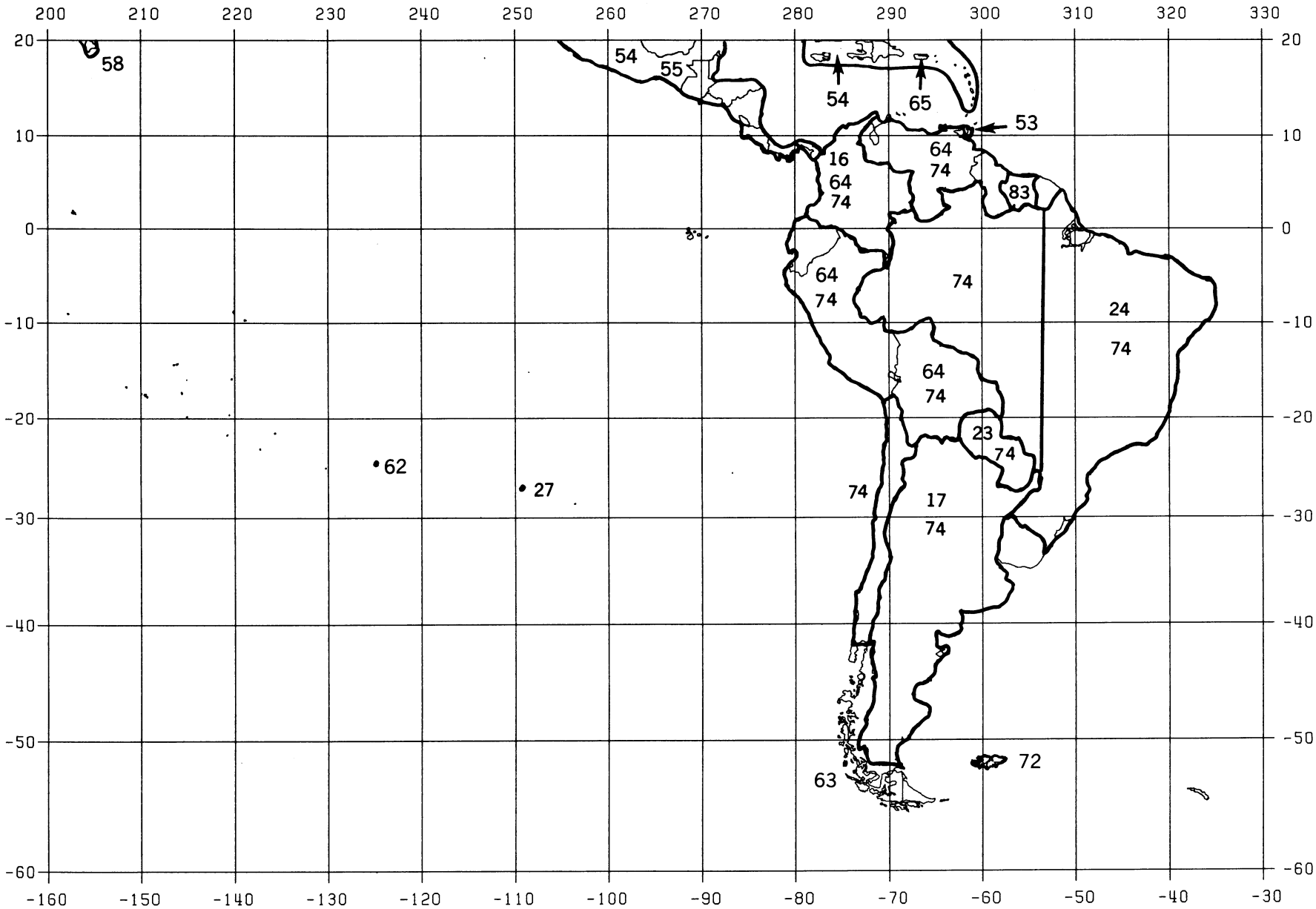

Figure 8.1b. Local Geodetic Systems (Table 8.5) Related to WGS 84

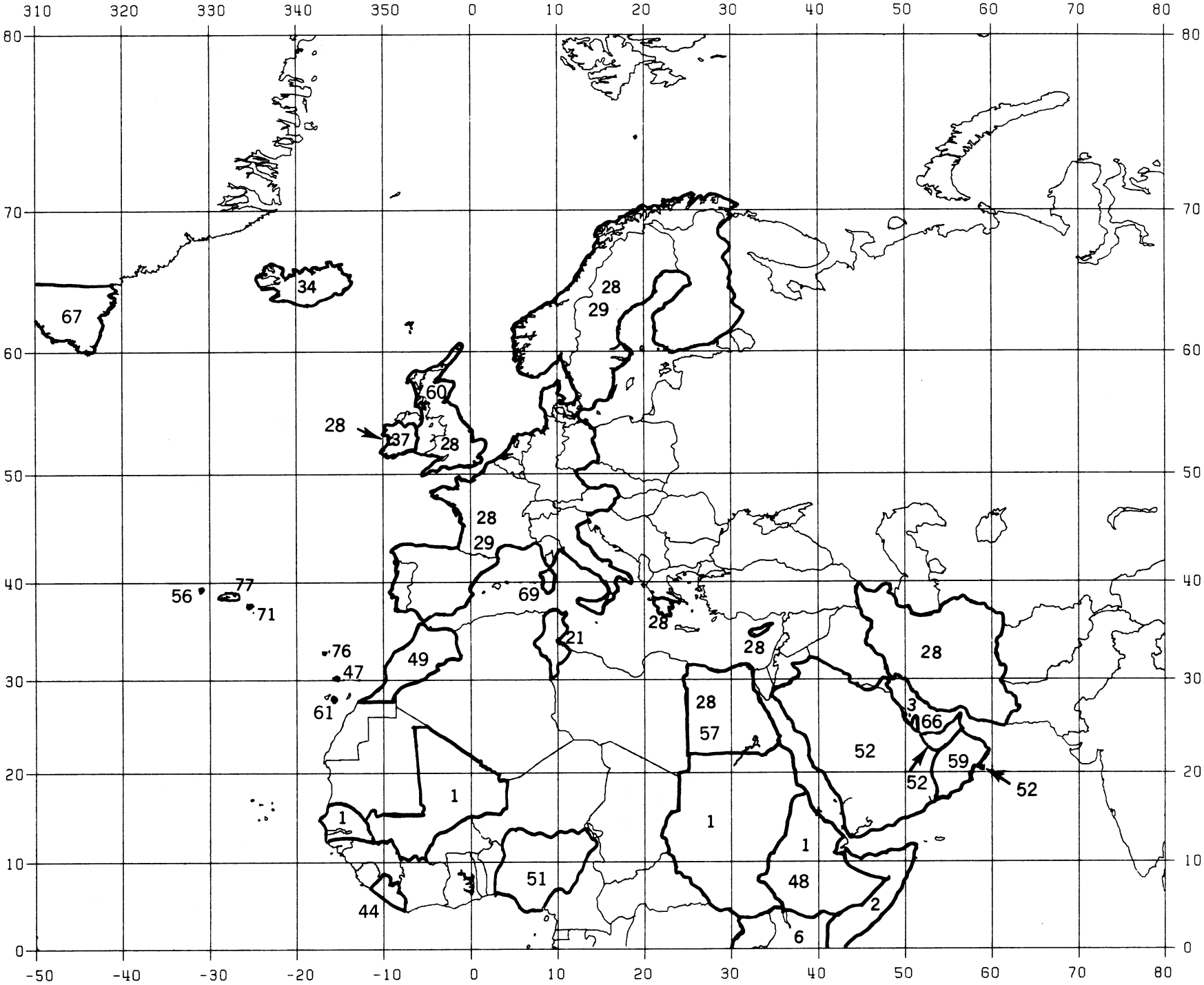

Figure 8.1c. Local Geodetic Systems (Table 8.5) Related to WGS 84

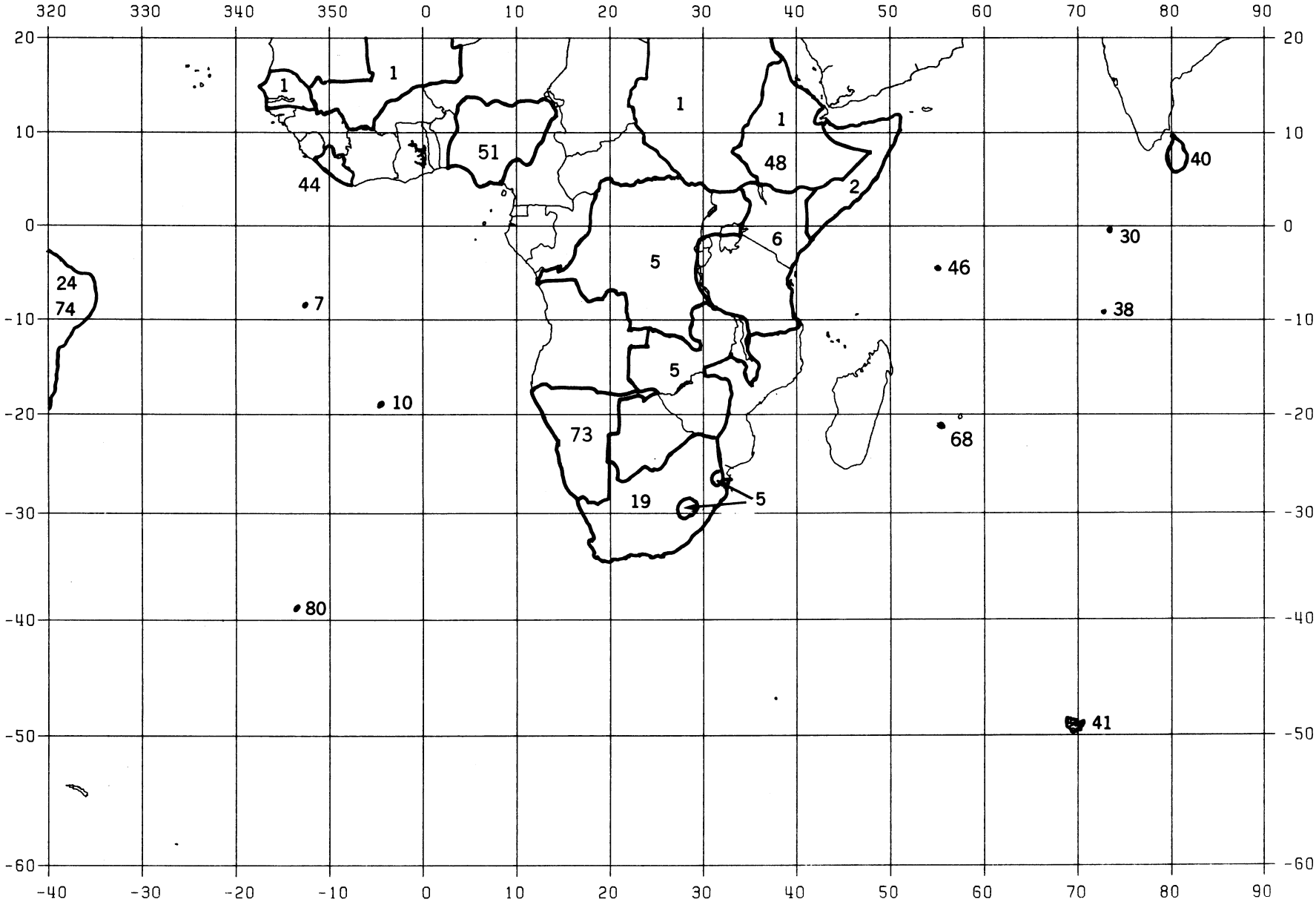

Figure 8.1d. Local Geodetic Systems (Table 8.5) Related to WGS 84

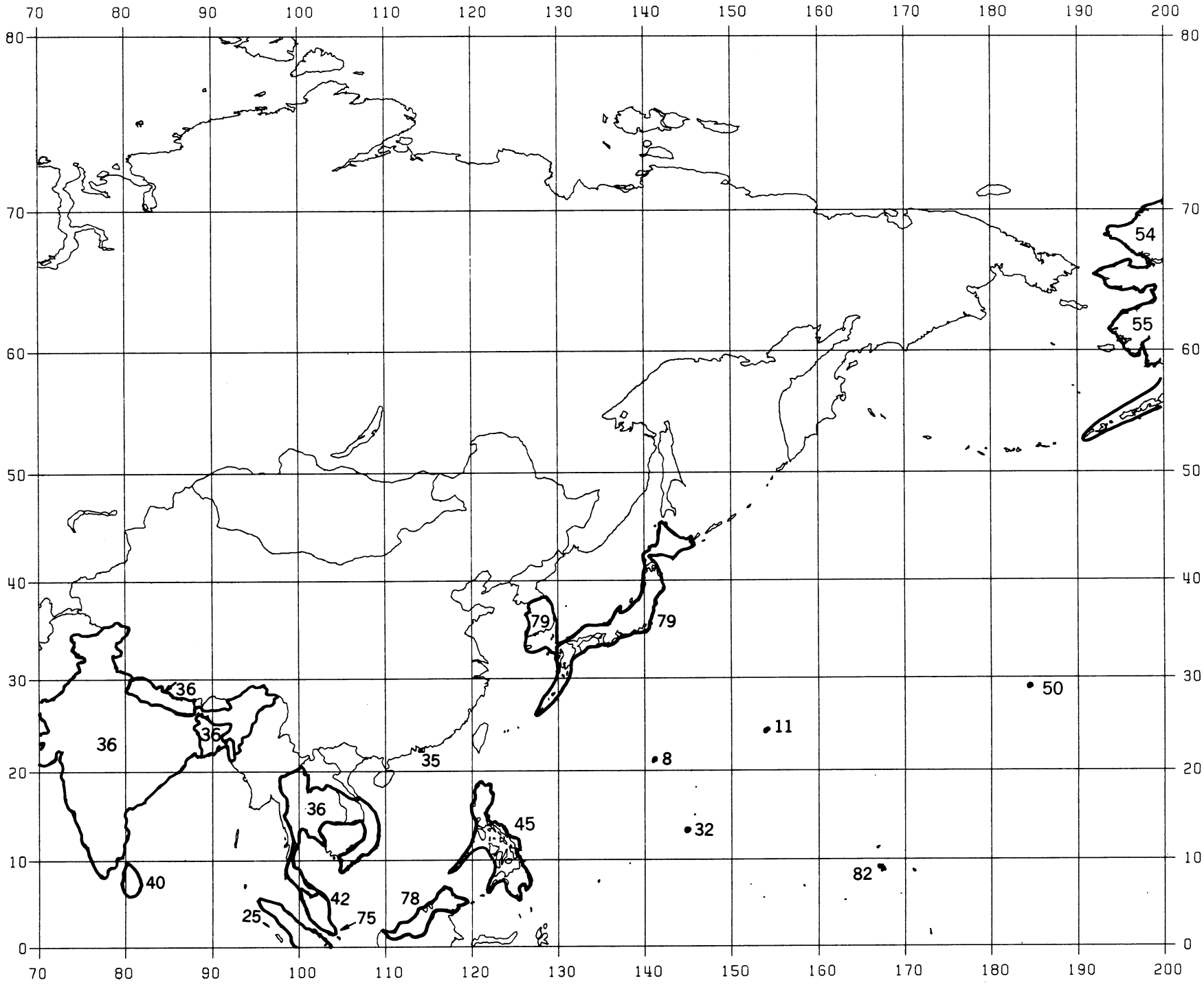

Figure 8.1e. Local Geodetic Systems (Table 8.5) Related to WGS 84

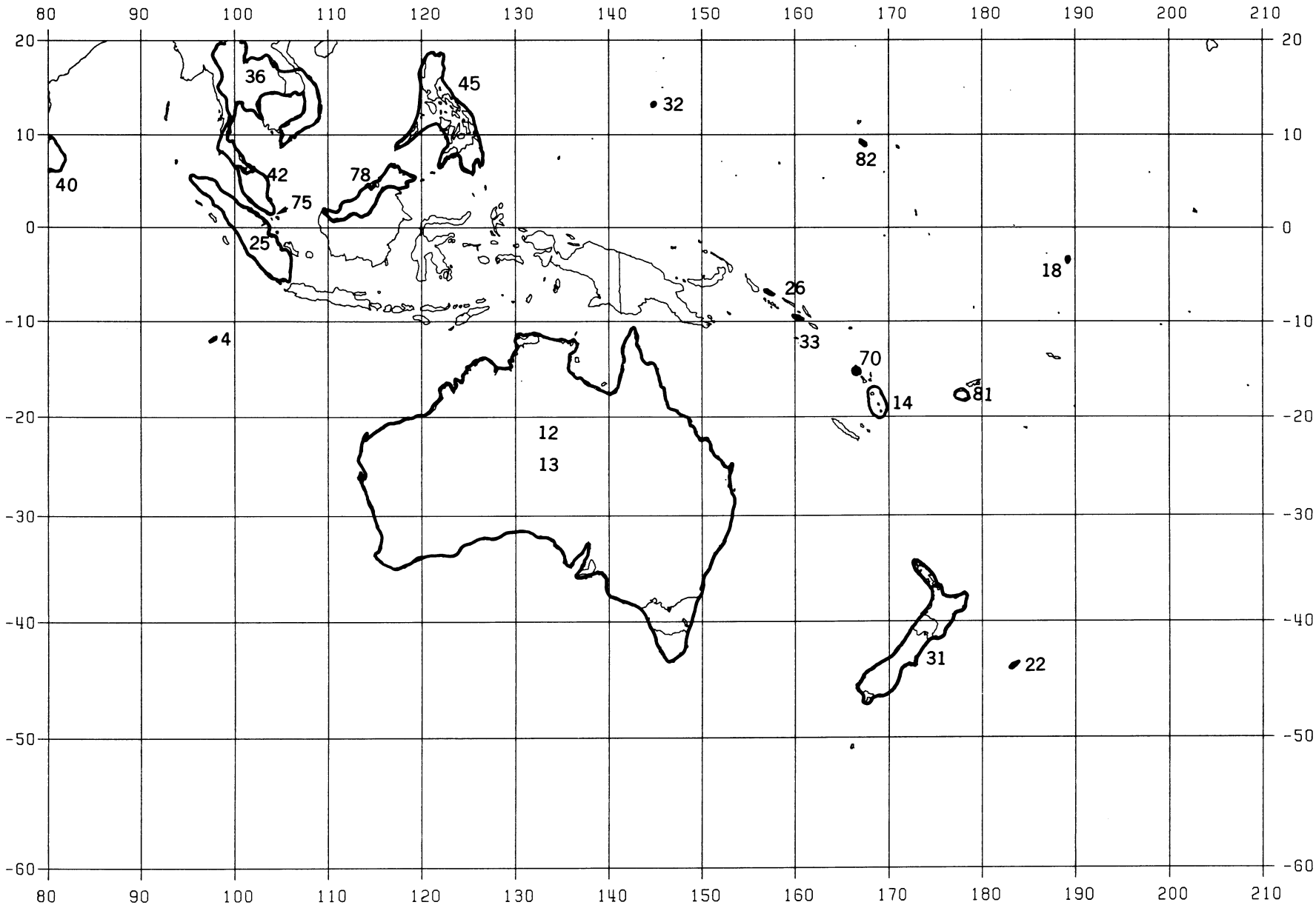

Figure 8.1f. Local Geodetic Systems (Table 8.5) Related to WGS 84

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SECTION 9

LOCAL GEODETIC SYSTEM-TO-WGS 84

MEAN DATUM SHIFTS ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) FOR MAJOR DATUMS

Table 9.1

Local Geodetic System-To-WGS 84

Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) for Major Datums

Local Geodetic System	Country (or Geographic Area)	Mean Datum Shifts			Number of Doppler Stations Used
		$\overline{\Delta X}$ (m)	$\overline{\Delta Y}$ (m)	$\overline{\Delta Z}$ (m)	
NAD 27*	CONUS	- 8	160	176	405
NAD 83*	CONUS	0	0	0	216
SAD 69	South America	- 57	1	- 41	84
ED 50**	Western Europe	- 87	- 98	-121	85
ED 50***	UK/Ireland	- 86	- 96	-120	47
ED 50***	UK	- 86	- 96	-120	40
TD	Japan/Korea/Okinawa	-128	481	664	13
AGD 66	Australia	-133	- 48	148	105
AGD 84	Australia	-134	- 48	149	90

* CONUS = Contiguous United States

** Western Europe = Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland

*** These ED 50 coordinates developed from Ordnance Survey of Great Britain (OSGB) Scientific Network (SN 80) coordinates

Table 9.2

Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) and Their Differences
- Local Geodetic System-to-WGS 84 and WGS 72 -

Local Geodetic Systems	Mean Datum Shifts 1984 $\overline{\Delta X}$ (m)	1984 $\overline{\Delta Y}$ (m)	1984 $\overline{\Delta Z}$ (m)	1972 $\overline{\Delta X}$ (m)	1972 $\overline{\Delta Y}$ (m)	1972 $\overline{\Delta Z}$ (m)	Differences (Absolute) $\overline{\delta\Delta X}$ (m)	$\overline{\delta\Delta Y}$ (m)	$\overline{\delta\Delta Z}$ (m)	Doppler Stations Used 1984	1972
NAD 27*	- 8	160	176	- 22	157	176	14	3	0	405	38
NAD 83*	0	0	0	---	---	---	--	--	-	216	--
SAD 69	- 57	1	- 41	- 77	3	-45	20	2	4	84	1
ED 50**	- 87	- 98	-121	- 84	-103	-127	3	5	6	85	8
ED 50***	- 86	- 96	-120	---	---	---	--	--	-	47	--
ED 50****	- 86	- 96	-120	---	---	---	--	--	-	40	--
TD	-128	481	664	-140	516	673	12	35	9	13	4
AGD 66	-133	- 48	148	-122	- 41	146	11	7	2	105	4
AGD 84	-134	- 48	149	---	---	---	--	--	-	90	--

* CONUS = Contiguous United States

** Western Europe = Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland

*** United Kingdom (UK)/Ireland; these ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates

**** UK only; these ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates

Table 9.3

RMS Differences
Between "Observed (Doppler)" WGS 84 Coordinates and Computed* WGS 84 Coordinates

Local Geodetic System	Country or Geographic Area	RMS Differences			Number of Doppler Stations Used
		Latitude	Longitude	Height	
NAD 27	CONUS	±4.3 m	±2.7 m	±2.0 m	405
NAD 83	CONUS	0.7	0.9	0.7	216
SAD 69	South America	5.5	10.0	3.7	84
ED 50	Western Europe**	2.3	4.9	1.8	85
ED 50***	UK/Ireland	0.7	0.9	1.4	47
ED 50***	UK	0.8	1.0	1.6	40
TD	Japan/Korea/Okinawa	4.6	5.0	2.0	13
AGD 66	Australia	2.1	1.9	1.6	105
AGD 84	Australia	1.1	1.1	1.6	90

CONUS = Contiguous United States; UK = United Kingdom

* Computed Using Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Abridged Molodensky Datum Transformation Formulas

** Western Europe = Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland

*** These ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates

SECTION 10

LOCAL GEODETIC SYSTEM-TO-WGS 84

DATUM TRANSFORMATION PARAMETERS FOR 83 LOCAL GEODETIC SYSTEMS

- [MEAN AND REGIONAL DATUM SHIFTS ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) , ELLIPSOID PARAMETER DIFFERENCES (Δa, Δf)] -

Table 10.1
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
ADINDAN	Clarke 1880	-112.145	-0.54750714				
Mean Value (Ethiopia and Sudan)				22	-166 ±5	-15 ±5	204 ±3
Ethiopia				8	-165 ±3	-11 ±3	206 ±3
Mali				1	-123 ±5	-20 ±5	220 ±5
Senegal				2	-128 ±4	-18 ±12	224 ±14
Sudan				14	-161 ±3	-14 ±5	205 ±3
AFGOOYE	Krassovsky	-108	0.00480795				
Somalia				1	- 43 ±5	-163 ±5	45 ±5
AIN EL ABD 1970	International	-251	-0.14192702				
Bahrain Island				1	-150 ±5	-251 ±5	-2 ±5
ANNA 1 ASTRO 1965	Australian National	-23	-0.00081204				
Cocos Islands				1	-491 ±5	-22 ±5	435 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
ARC 1950	Clarke 1880	-112.145	-0.54750714				
Mean Value (Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, and Zimbabwe)				41	-143 ±20	-90 ±33	-294 ±20
Botswana				9	-138 ±3	-105 ±5	-289 ±3
Lesotho				5	-125 ±3	-108 ±3	-295 ±8
Malawi				6	-161 ±9	-73 ±24	-317 ±8
Swaziland				4	-134 ±3	-105 ±3	-295 ±3
Zaire				2	-169 ±18	-19 ±4	-278 ±4
Zambia				5	-147 ±21	-74 ±21	-283 ±27
Zimbabwe				10	-142 ±5	-96 ±8	-293 ±11

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
ARC 1960 Mean Value (Kenya, Tanzania)	Clarke 1880	-112.145	-0.54750714	19	-160 ±6	-8 ±9	-300 ±6
Kenya				12	-161 ±3	-7 ±5	-300 ±5
Tanzania				7	-158 ±9	-12 ±12	-299 ±11
ASCENSION ISLAND 1958 Ascension Island	International	-251	-0.14192702	1	-207 ±5	107 ±5	52 ±5
ASTRO BEACON "E" Iwo Jima Island	International	-251	-0.14192702	1	145 ±5	75 ±5	-272 ±5
ASTRO B4 SOROL ATOLL Tern Island	International	-251	-0.14192702	1	114 ±5	-116 ±5	-333 ±5
ASTRO DOS 71/4 St. Helena Island	International	-251	-0.14192702	1	-320 ±5	550 ±5	-494 ±5
ASTRONOMIC STATION 1952 Marcus Island	International	-251	-0.14192702	1	124 ±5	-234 ±5	-25 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
AUSTRALIAN GEODETIC 1966 Australia and Tasmania Island	Australian National	-23	-0.00081204	105	-133 ±3	-48 ±3	148 ±3
AUSTRALIAN GEODETIC 1984 Australia and Tasmania Island	Australian National	-23	-0.00081204	90	-134 ±3	-48 ±3	149 ±3
BELLEVUE (IGN) Efate and Erromango Islands	International	-251	-0.14192702	3	-127 ±3	-769 ±3	472 ±3
BERMUDA 1957 Bermuda Islands	Clarke 1866	-69.4	-0.37264639	3	-73 ±3	213 ±5	296 ±3
BOGOTA OBSERVATORY Colombia	International	-251	-0.14192702	7	307 ±6	304 ±5	-318 ±6
CAMPO INCHAUSPE Argentina	International	-251	-0.14192702	20	-148 ±5	136 ±5	90 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

[Revised: 30 September 1988

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
CANTON ASTRO 1966 Phoenix Islands	International	-251	-0.14192702	4	298 ±3	-304 ±3	-375 ±3
CAPE South Africa	Clarke 1880	-112.145	-0.54750714	5	-136 ±3	-108 ±6	-292 ±6
CAPE CANAVERAL Mean Value (Florida and Bahama Islands)	Clarke 1866	-69.4	-0.37264639	16	-2 ±3	150 ±3	181 ±3
CARTHAGE Tunisia	Clarke 1880	-112.145	-0.54750714	5	-263 ±6	6 ±9	431 ±8
CHATHAM 1971 Chatham Island (New Zealand)	International	-251	-0.14192702	4	175 ±3	-38 ±3	113 ±3
CHUA ASTRO Paraguay	International	-251	-0.14192702	6	-134 ±6	229 ±9	-29 ±5
CORREGO ALEGRE Brazil	International	-251	-0.14192702	17	-206 ±5	172 ±3	-6 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
DJAKARTA (BATAVIA) Sumatra Island (Indonesia)	Bessel 1841	739.845	0.10037483	5	-377 ±3	681 ±3	-50 ±3
DOS 1968 Gizo Island (New Georgia Islands)	International	-251	-0.14192702	1	230 ±5	-199 ±5	-752 ±5
EASTER ISLAND 1967 Easter Island	International	-251	-0.14192702	1	211 ±5	147 ±5	111 ±5
EUROPEAN 1950 Mean Value [Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland]	International	-251	-0.14192702	85	-87 ±3	-98 ±8	-121 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
EUROPEAN 1950 (Cont'd)	International	-251	-0.14192702				
Western Europe (Limited to Austria, Denmark, France, Federal Republic of Germany, Netherlands, and Switzerland)				52	-87 ±3	-96 ±3	-120 ±3
Cyprus				4	-104 ±3	-101 ±3	-140 ±3
Egypt				14	-130 ±6	-117 ±8	-151 ±8
England, Channel Islands, Scotland, and Shetland Islands***				40	-86 ±3	-96 ±3	-120 ±3
England, Ireland, Scotland, and Shetland Islands***				47	-86 ±3	-96 ±3	-120 ±3
Greece				2	-84 ±4	-95 ±6	-130 ±4
Iran				27	-117 ±9	-132 ±12	-164 ±11
Italy							
Sardinia				2	-97 ±10	-103 ±4	-120 ±8
Sicily				3	-97 ±3	-88 ±3	-135 ±3
Norway and Finland				20	-87 ±3	-95 ±5	-120 ±3

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

*** European Datum 1950 coordinates developed from Ordnance Survey of Great Britain (OSGB) Scientific Network 1980 (SN 80) coordinates.

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
EUROPEAN 1950 (Cont'd) Portugal and Spain	International	-251	-0.14192702	10	-88 ±5	-109 ±6	-122 ±3
EUROPEAN 1979 Mean Value (Austria, Finland, Netherlands, Norway, Spain, Sweden, and Switzerland)	International	-251	-0.14192702	22	-86 ±3	-98 ±3	-119 ±3
GANDAJIKA BASE Republic of Maldives	International	-251	-0.14192702	1	-133 ±5	-321 ±5	50 ±5
GEODETIC DATUM 1949 New Zealand	International	-251	-0.14192702	14	84 ±5	-22 ±3	209 ±5
GUAM 1963 Guam Island	Clarke 1866	-69.4	-0.37264639	5	-100 ±3	-248 ±3	259 ±3
GUX 1 ASTRO Guadalcanal Island	International	-251	-0.14192702	1	252 ±5	-209 ±5	-751 ±5
HJORSEY 1955 Iceland	International	-251	-0.14192702	6	-73 ±3	46 ±3	-86 ±6

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

[Revised: 30 September 1987

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
HONG KONG 1963 Hong Kong	International	-251	-0.14192702	2	-156 ±4	-271 ±4	-189 ±4
INDIAN Thailand and Vietnam Bangladesh, India, and Nepal	Everest	860.655	0.28361368	14 13	214 ±9 289 ±6	836 ±3 734 ±6	303 ±8 257 ±6
IRELAND 1965 Ireland	Modified Airy	796.811	0.11960023	7	506 ±3	-122 ±3	611 ±3
ISTS 073 ASTRO 1969 Diego Garcia	International	-251	-0.14192702	2	208 ±4	-435 ±4	-229 ±4
JOHNSTON ISLAND 1961 Johnston Island	International	-251	-0.14192702	1	191 ±5	-77 ±5	-204 ±5
KANDAWALA Sri Lanka	Everest	860.655	0.28361368	3	-97 ±3	787 ±3	86 ±3
KERGUELEN ISLAND Kerguelen Island	International	-251	-0.14192702	1	145 ±5	-187 ±5	103 ±5
KERTAU 1948 West Malaysia and Singapore	Modified Everest	832.937	0.28361368	6	-11 ±3	851 ±3	5 ±3

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
L.C. 5 ASTRO Cayman Brac Island	Clarke 1866	-69.4	-0.37264639	1	42 ±5	124 ±5	147 ±5
LIBERIA 1964 Liberia	Clarke 1880	-112.145	-0.54750714	4	-90 ±5	40 ±12	88 ±5
LUZON Philippines (Excluding Mindanao Island)	Clarke 1866	-69.4	-0.37264639	6	-133 ±8	-77 ±11	-51 ±9
Mindanao Island				1	-133 ±5	-79 ±5	-72 ±5
MAHE 1971 Mahe Island	Clarke 1880	-112.145	-0.54750714	1	41 ±5	-220 ±5	-134 ±5
MARCO ASTRO Salvage Islands	International	-251	-0.14192702	1	-289 ±5	-124 ±5	60 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
MASSAWA Eritrea (Ethiopia)	Bessel 1841	739.845	0.10037483	1	639 ±5	405 ±5	60 ±5
MERCHICH Morocco	Clarke 1880	-112.145	-0.54750714	9	31 ±5	146 ±3	47 ±3
MIDWAY ASTRO 1961 Midway Island	International	-251	-0.14192702	1	912 ±5	-58 ±5	1227 ±5
MINNA Nigeria	Clarke 1880	-112.145	-0.54750714	6	-92 ±3	-93 ±6	122 ±5
NAHRWAN Masirah Island (Oman)	Clarke 1880	-112.145	-0.54750714	2	-247 ±4	-148 ±8	369 ±12
United Arab Emirates				2	-249 ±4	-156 ±8	381 ±12
Saudi Arabia				1	-231 ±5	-196 ±5	482 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
NAPARIMA, BWI Trinidad and Tobago	International	-251	-0.14192702	1	-2 ±5	374 ±5	172 ±5
NORTH AMERICAN 1927 Mean Value (CONUS)	Clarke 1866	-69.4	-0.37264639	405	-8 ±5	160 ±5	176 ±6
Western United States (Arizona, Arkansas, California, Colorado, Idaho, Iowa, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming)				276	-8 ±5	159 ±3	175 ±3
Eastern United States (Alabama, Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Indiana, Kentucky,				129	-9 ±5	161 ±5	179 ±8

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
NORTH AMERICAN 1927 (Cont'd) Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Vermont, Virginia, West Virginia, and Wisconsin)	Clarke 1866	-69.4	-0.37264639				
Alaska				47	-5 ±5	135 ±9	172 ±5
Bahamas (Excluding San Salvador Island)				11	-4 ±5	154 ±3	178 ±5
San Salvador Island				1	1 ±5	140 ±5	165 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
NORTH AMERICAN 1927 (Cont'd)	Clarke 1866	-69.4	-0.37264639				
Canada (Including Newfoundland Island)				112	-10 ±15	158 ±11	187 ±6
Alberta and British Columbia				25	-7 ±8	162 ±8	188 ±6
East Canada (Newfoundland, New Brunswick, Nova Scotia, and Quebec)				37	-22 ±6	160 ±6	190 ±3
Manitoba and Ontario				25	-9 ±9	157 ±5	184 ±5
Northwest Territories and Saskatchewan				17	4 ±5	159 ±5	188 ±3
Yukon				8	-7 ±5	139 ±8	181 ±3

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	Δf x 10^4		ΔX(m)	ΔY(m)	ΔZ(m)
NORTH AMERICAN 1927 (Cont'd)	Clarke 1866	-69.4	-0.37264639				
Canal Zone				3	0 ±6	125 ±3	201 ±5
Caribbean (Barbados, Caicos Islands, Cuba, Dominican Republic, Grand Cayman, Jamaica, Leeward Islands, and Turks Islands)				14	- 7 ±3	152 ±9	178 ±12
Central America (Belize, Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua)				19	0 ±8	125 ±3	194 ±5
Cuba				1	-9 ±5	152 ±5	178 ±5
Greenland (Hayes Peninsula)				2	11 ±4	114 ±4	195 ±10

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
NORTH AMERICAN 1927 (Cont'd)	Clarke 1866	-69.4	-0.37264639				
Mexico				22	-12 ±8	130 ±6	190 ±6
NORTH AMERICAN 1983	GRS 80	0	-0.00000016				
Alaska				42	0 ±2	0 ±2	0 ±2
Canada				96	0 ±2	0 ±2	0 ±2
CONUS				216	0 ±2	0 ±2	0 ±2
Mexico, Central America				25	0 ±2	0 ±2	0 ±2
OBSERVATORIO 1966	International	-251	-0.14192702				
Corvo and Flores Islands (Azores)				3	-425 ±6	-169 ±5	81 ±3
OLD EGYPTIAN	Helmert 1906	-63	0.00480795				
Egypt				14	-130 ±3	110 ±6	-13 ±8

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
OLD HAWAIIAN	Clarke 1866	-69.4	-0.37264639				
Mean Value				13	61 ±8	-285 ±5	-181 ±6
Hawaii				2	89 ±4	-279 ±4	-183 ±4
Kauai				3	45 ±3	-290 ±3	-172 ±3
Maui				2	65 ±4	-290 ±4	-190 ±4
Oahu				6	56 ±3	-284 ±3	-181 ±3
OMAN	Clarke 1880	-112.145	-0.54750714				
Oman				7	-346 ±3	-1 ±3	224 ±9
ORDNANCE SURVEY OF GREAT BRITAIN 1936	Airy	573.604	0.11960023				
Mean Value (England, Isle of Man, Scotland, Shetland Islands, and Wales)				38	375 ±10	-111 ±5	431 ±8
England				21	371 ±3	-112 ±3	434 ±3
England, Isle of Man, and Wales				25	371 ±3	-111 ±3	434 ±3

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
ORDNANCE SURVEY OF GREAT BRITAIN 1936 (Cont'd)	Airy	573.604	0.11960023				
Scotland and Shetland Islands				13	384 ±5	-111 ±6	425 ±3
Wales				3	370 ±3	-108 ±3	434 ±3
PICO DE LAS NIEVES Canary Islands	International	-251	-0.14192702	1	-307 ±5	-92 ±5	127 ±5
PITCAIRN ASTRO 1967 Pitcairn Island	International	-251	-0.14192702	1	185 ±5	165 ±5	42 ±5
PROVISIONAL SOUTH CHILEAN 1963*** South Chile (near 53°S)	International	-251	-0.14192702	2	16 ±4	196 ±4	93 ±8

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system
*** Also known as Hito XVIII 1963.

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
PROVISIONAL SOUTH AMERICAN 1956	International	-251	-0.14192702				
Mean Value (Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Venezuela)				63	-288 ±17	175 ±27	-376 ±27
Bolivia				5	-270 ±5	188 ±11	-388 ±14
Chile							
Northern Chile (near 19°S)				1	-270 ±5	183 ±5	-390 ±5
Southern Chile (near 43°S)				3	-305 ±3	243 ±5	-442 ±5
Colombia				4	-282 ±8	169 ±3	-371 ±6

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
PROVISIONAL SOUTH AMERICAN 1956 (Cont'd)	International	-251	-0.14192702				
Ecuador				11	-278 ±3	171 ±5	-367 ±3
Guyana				9	-298 ±6	159 ±14	-369 ±5
Peru				6	-279 ±6	175 ±8	-379 ±12
Venezuela				24	-295 ±9	173 ±14	-371 ±15
PUERTO RICO Puerto Rico and Virgin Islands	Clarke 1866	-69.4	-0.37264639	11	11 ±3	72 ±3	-101 ±3
QATAR NATIONAL Qatar	International	-251	-0.14192702	3	-128 ±3	-283 ±3	22 ±3
QORNOQ South Greenland	International	-251	-0.14192702	2	164 ±4	138 ±6	-189 ±32
REUNION Mascarene Island	International	-251	-0.14192702	1	94 ±5	-948 ±5	-1262 ±5
ROME 1940 Sardinia Island	International	-251	-0.14192702	1	-225 ±5	-65 ±5	9 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
SANTO (DOS) Espirito Santo Island	International	-251	-0.14192702	1	170 ±5	42 ±5	84 ±5
SÃO BRAZ São Miguel, Santa Maria Islands (Azores)	International	-251	-0.14192702	2	-203 ±4	141 ±4	53 ±4
SAPPER HILL 1943 East Falkland Island	International	-251	-0.14192702	1	-355 ±5	16 ±5	74 ±5
SCHWARZECK Namibia	Bessel 1841	653.135****	0.10037483	3	616 ±6	97 ±5	-251 ±11
SOUTH AMERICAN 1969 Mean Value (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Trinidad and Tobago, and Venezuela)	South American 1969	-23	-0.00081204	84	-57 ±15	1 ±6	-41 ±9

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system
**** This Δa value reflects an a-value of 6377483.865 meters for the Bessel 1841 Ellipsoid in Namibia.

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
SOUTH AMERICAN 1969 (Cont'd)	South American 1969	-23	-0.00081204				
Argentina				10	-62 ±5	-1 ±5	-37 ±5
Bolivia				4	-61 ±3	2 ±8	-48 ±6
Brazil				22	-60 ±3	-2 ±5	-41 ±5
Chile				9	-75 ±15	-1 ±8	-44 ±11
Colombia				7	-44 ±6	6 ±6	-36 ±5
Ecuador				11	-48 ±3	3 ±3	-44 ±3
Guyana				5	-53 ±9	3 ±5	-47 ±5
Paraguay				4	-61 ±5	2 ±6	-33 ±3
Peru				6	-58 ±5	0 ±5	-44 ±5

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
SOUTH AMERICAN 1969 (Cont'd)	South American 1969	-23	-0.00081204				
Trinidad and Tobago				1	-45 ±5	12 ±5	-33 ±5
Venezuela				5	-45 ±3	8 ±6	-33 ±3
SOUTH ASIA	Modified Fischer 1960	-18	0.00480795				
Singapore				1	7 ±5	-10 ±5	-26 ±5
SOUTHEAST BASE	International	-251	-0.14192702				
Porto Santo and Madeira Islands				2	-499 ±4	-249 ±4	314 ±4

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
SOUTHWEST BASE Faial, Graciosa, Pico, São Jorge, and Terceira Islands (Azores)	International	-251	-0.14192702	5	-104 ±3	167 ±3	-38 ±3
TIMBALAI 1948 Brunei and East Malaysia (Sarawak and Sabah)	Everest	860.655	0.28361368	8	-689 ±5	691 ±3	-46 ±6
TOKYO Mean Value (Japan, Korea, and Okinawa)	Bessel 1841	739.845	0.10037483	13	-128 ±8	481 ±5	664 ±6
Japan				3	-123 ±6	483 ±9	662 ±12
Korea				8	-128 ±5	481 ±3	665 ±3
Okinawa				2	-135 ±4	478 ±4	661 ±4

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

Table 10.1 (Cont'd)
Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	$\Delta f \times 10^4$		ΔX(m)	ΔY(m)	ΔZ(m)
TRISTAN ASTRO 1968 Tristan da Cunha	International	-251	-0.14192702	1	-632 ±5	438 ±5	-609 ±5
VITI LEVU 1916 Viti Levu Island (Fiji Islands)	Clarke 1880	-112.145	-0.54750714	1	51 ±5	391 ±5	-36 ±5
WAKE-ENIWETOK 1960 Marshall Islands	Hough	-133	-0.14192702	7	101 ±3	52 ±3	-39 ±3
ZANDERIJ Surinam	International	-251	-0.14192702	5	-265 ±5	120 ±5	-358 ±8

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n=m=180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.
** WGS 84 minus local geodetic system

NOTE: See Section 12 for Non-Doppler Derived Local Geodetic System-to-WGS 84 Datum Transformation Parameters.

SECTION 11

HISTOGRAMS

- WGS 84 COORDINATE DIFFERENCES* (MAJOR DATUMS) -

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* WGS 84 COORDINATES OBTAINED FROM DOPPLER-DERIVED NSWC 9Z-2 COORDINATES USING NSWC 9Z-2 TO WGS 84 TRANSFORMATION MINUS 84 COORDINATES COMPUTED USING LOCAL GEODETIC SYSTEM-TO-WGS 84 MEAN DATUM SHIFTS ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$), TABLE 9.1, IN THE MOLODENSKY DATUM TRANSFORMATION FORMULAS, TABLE 6.4; UNITS = METERS

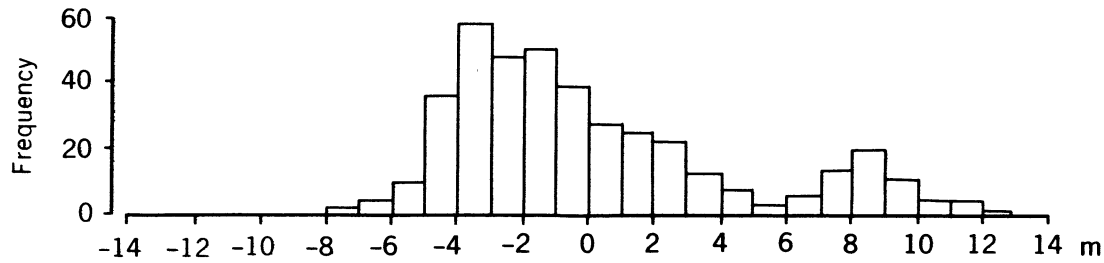

Figure 11.1a. NAD 27 (CONUS)-Geodetic Latitude Differences*

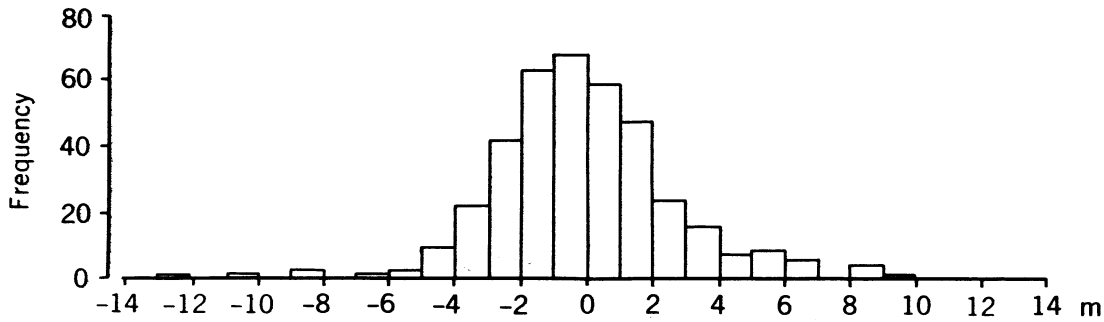

Figure 11.1b. NAD 27 (CONUS)-Geodetic Longitude Differences*

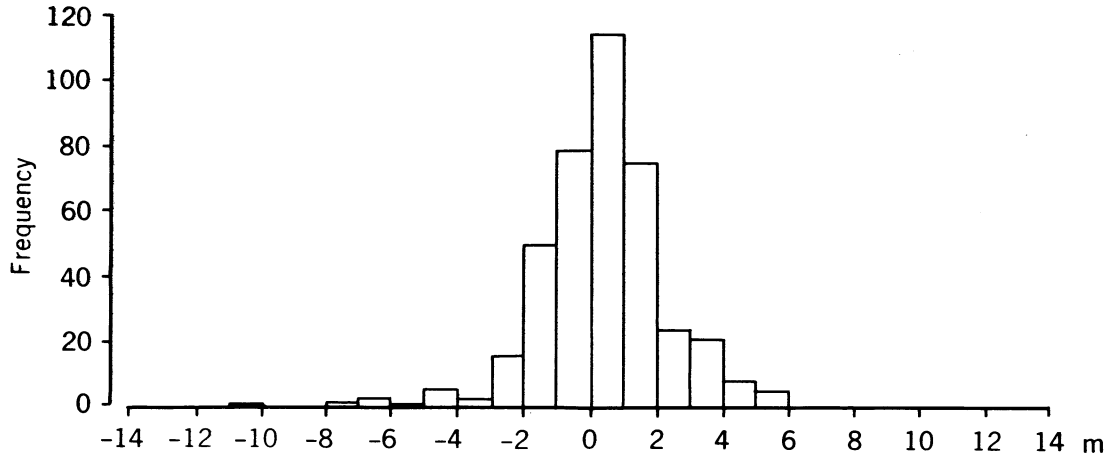

Figure 11.1c. NAD 27 (CONUS)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using NAD 27 (CONUS)-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

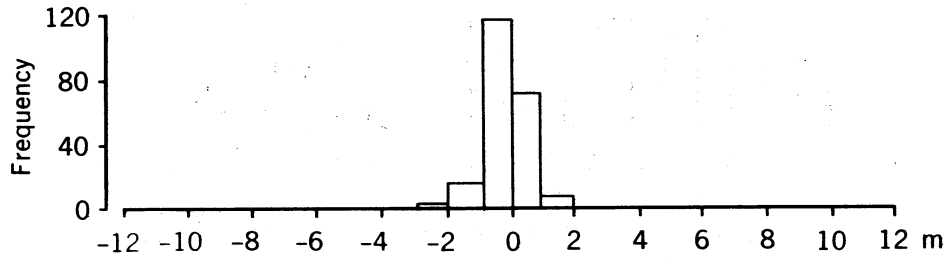

Figure 11.2a. NAD 83 (CONUS)-Geodetic Latitude Differences*

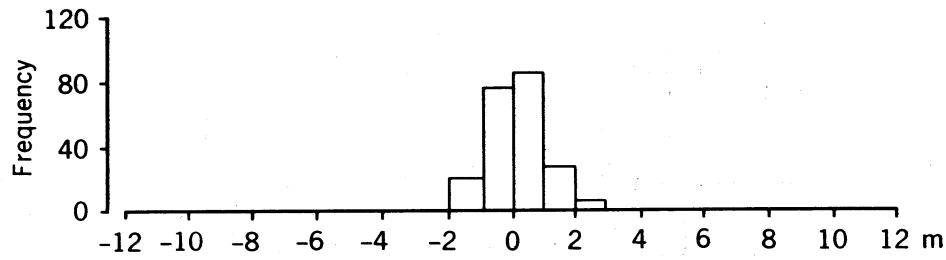

Figure 11.2b. NAD 83 (CONUS)-Geodetic Longitude Differences*

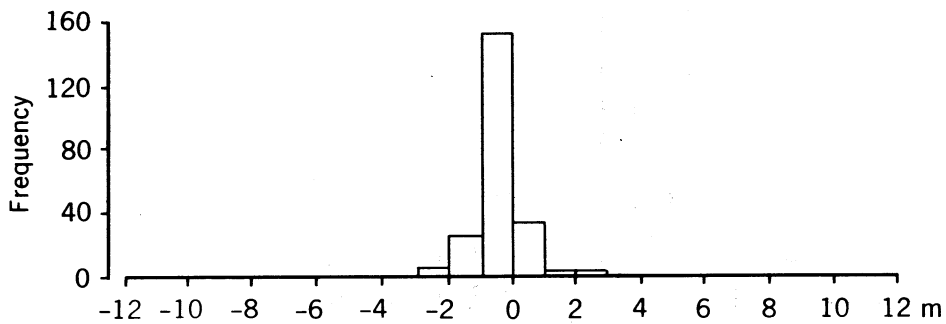

Figure 11.2c. NAD 83 (CONUS)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using NAD 83 (CONUS)-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

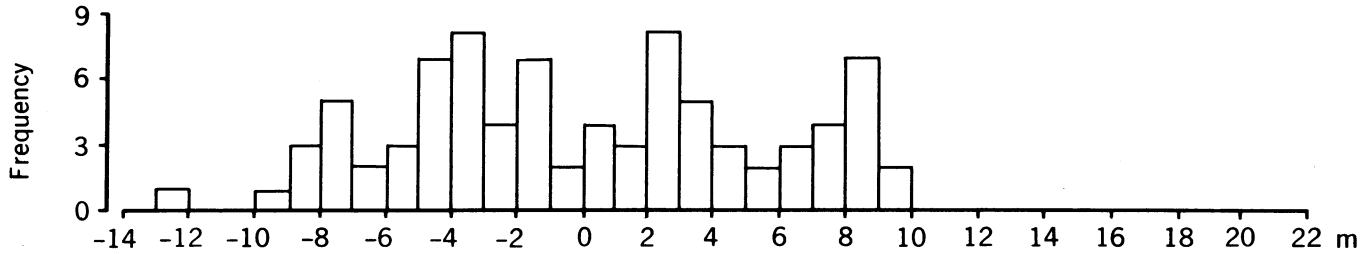

Figure 11.3a. SAD 69-Geodetic Latitude Differences*

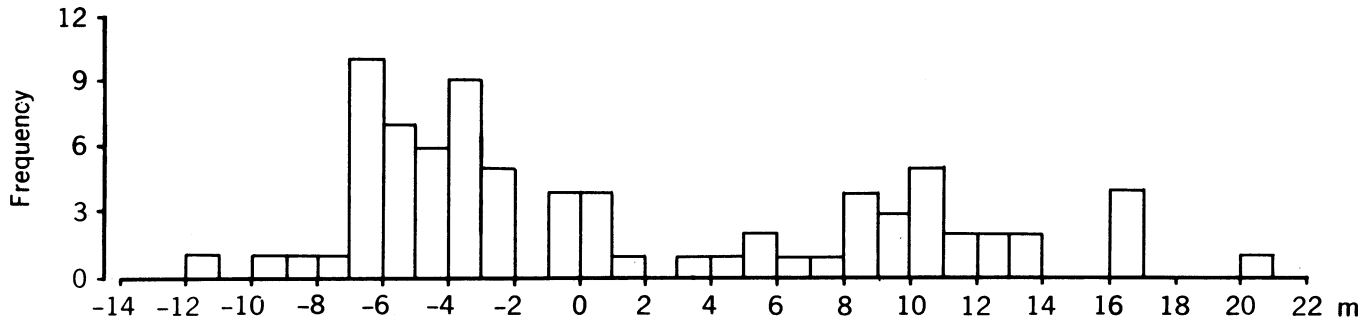

Figure 11.3b. SAD 69-Geodetic Longitude Differences*

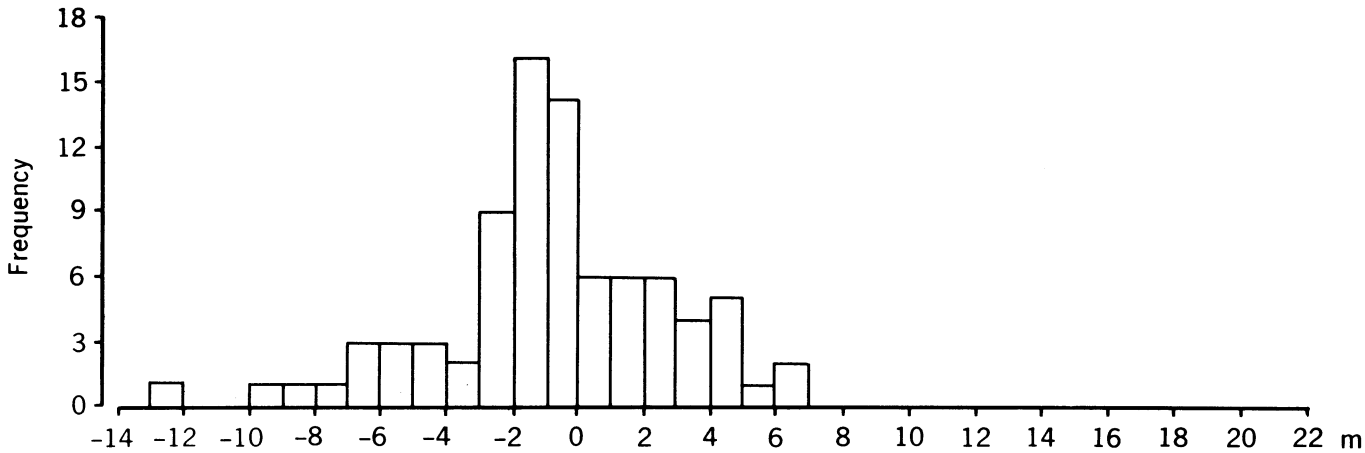

Figure 11.3c. SAD 69-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using SAD 69-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

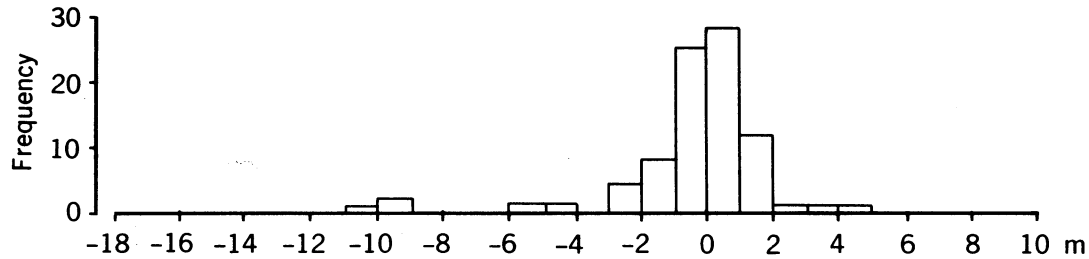

Figure 11.4a. ED 50 (Western Europe)-Geodetic Latitude Differences*

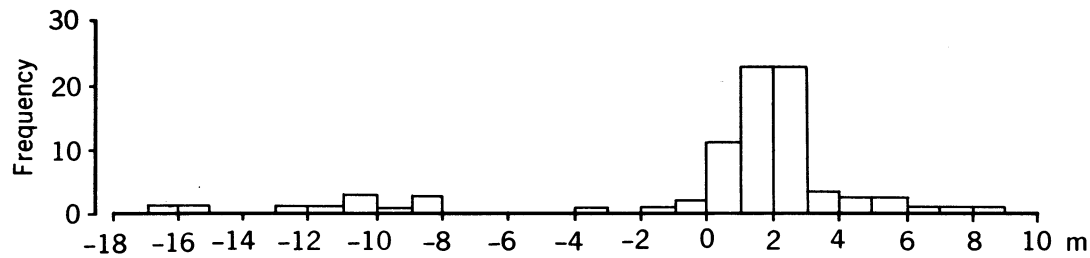

Figure 11.4b. ED 50 (Western Europe)-Geodetic Longitude Differences*

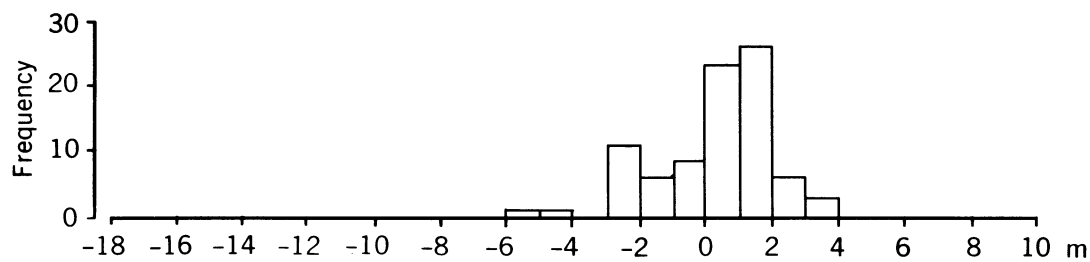

Figure 11.4c. ED 50 (Western Europe)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using ED 50 (Western Europe)-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

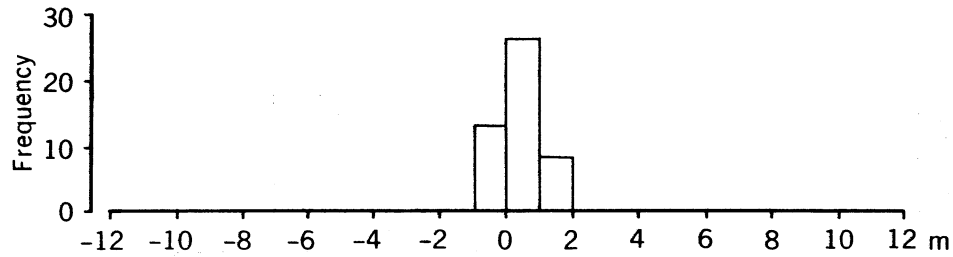

Figure 11.5a. ED 50 (UK/Ireland)-Geodetic Latitude Differences*

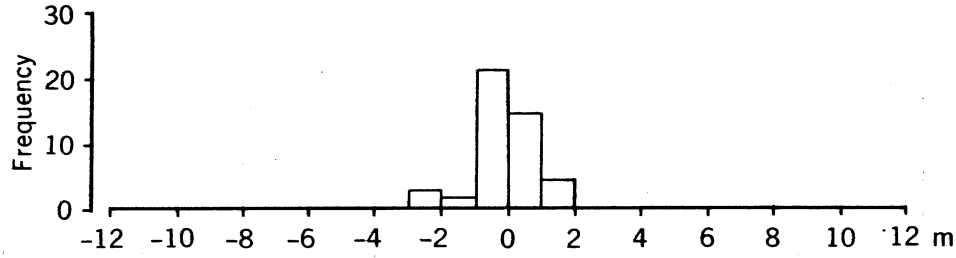

Figure 11.5b. ED 50 (UK/Ireland)-Geodetic Longitude Differences*

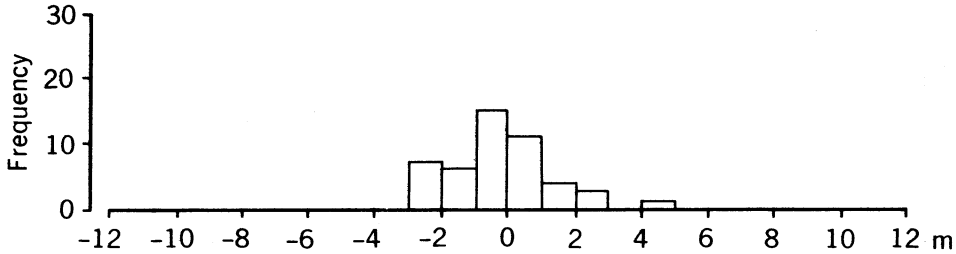

Figure 11.5c. ED 50 (UK/Ireland)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using ED 50 (UK/Ireland)-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

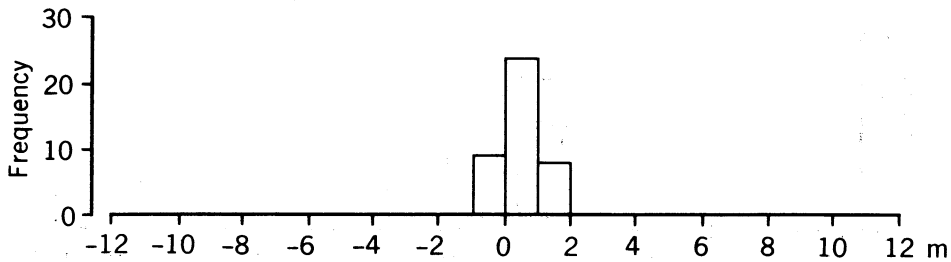

Figure 11.6a. ED 50 (UK Only)-Geodetic Latitude Differences*

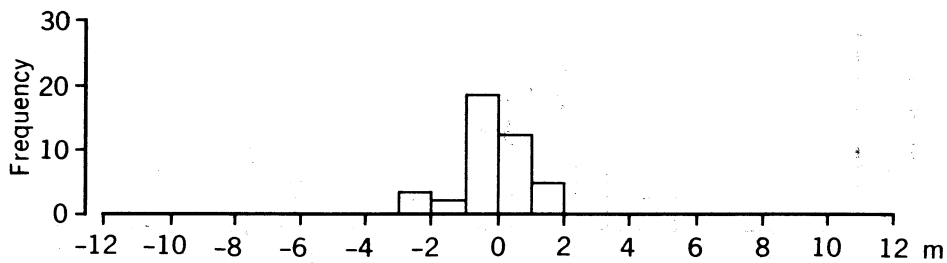

Figure 11.6b. ED 50 (UK Only)-Geodetic Longitude Differences*

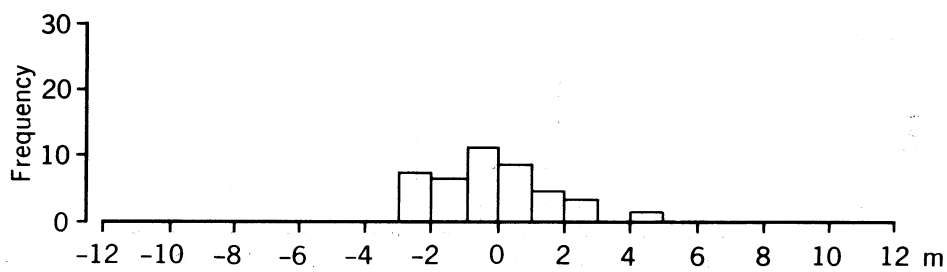

Figure 11.6c. ED 50 (UK Only)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using ED 50 (UK Only)-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

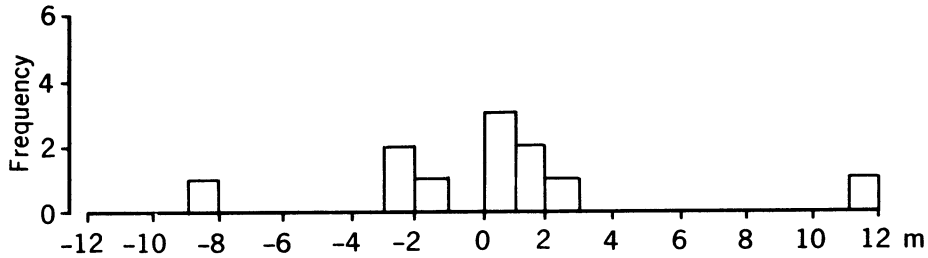

Figure 11.7a. TD-Geodetic Latitude Differences*

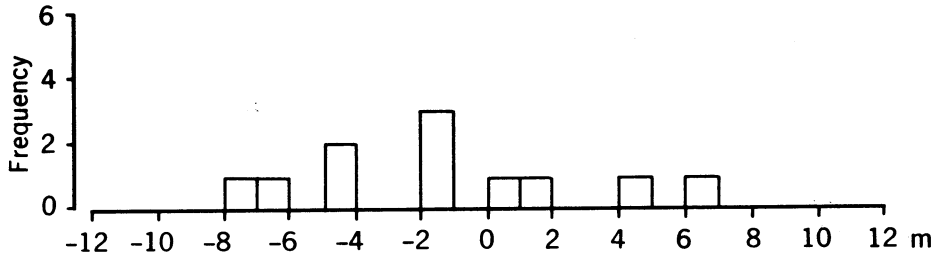

Figure 11.7b. TD-Geodetic Longitude Differences*

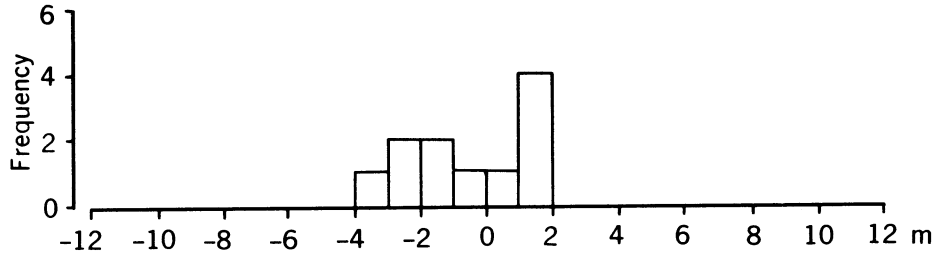

Figure 11.7c. TD-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using TD-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

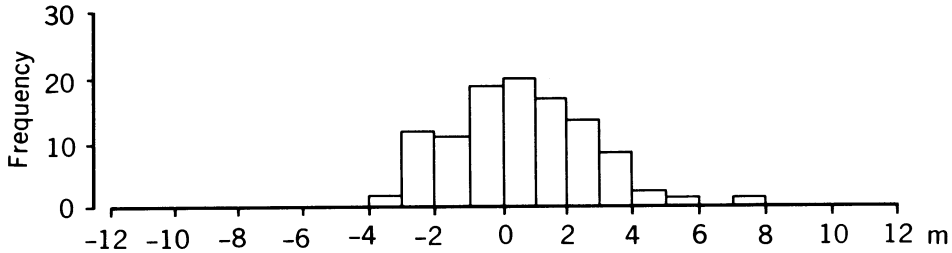

Figure 11.8a. AGD 66-Geodetic Latitude Differences*

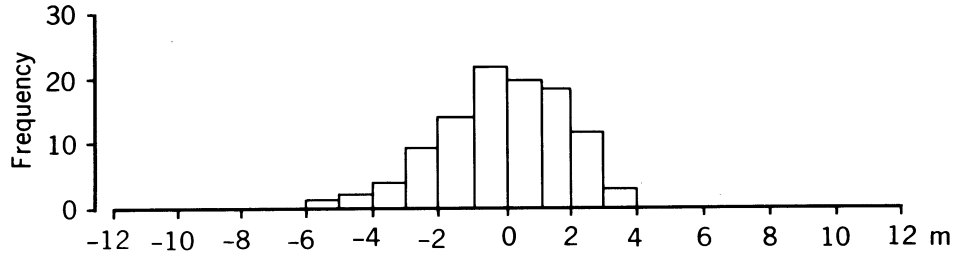

Figure 11.8b. AGD 66-Geodetic Longitude Differences*

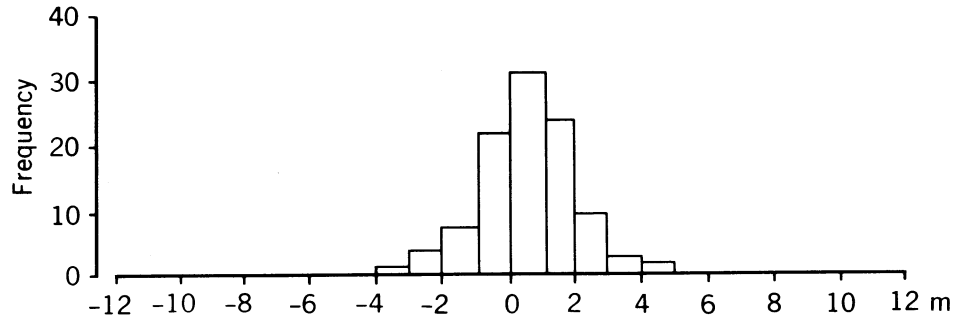

Figure 11.8c. AGD 66-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using AGD 66-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$)in the Molodensky Datum Transformation Formulas.

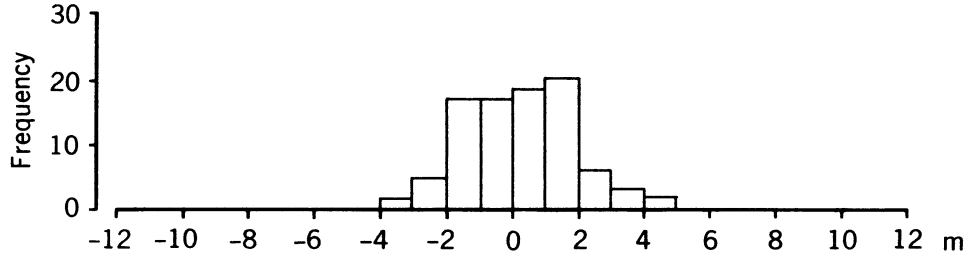

Figure 11.9a. AGD 84 - Geodetic Latitude Differences*

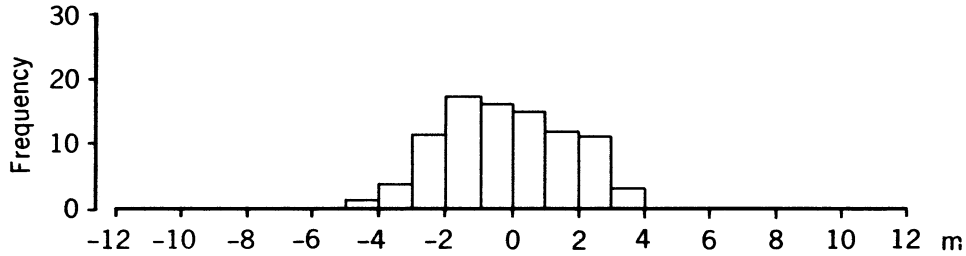

Figure 11.9b. AGD 84 - Geodetic Longitude Differences*

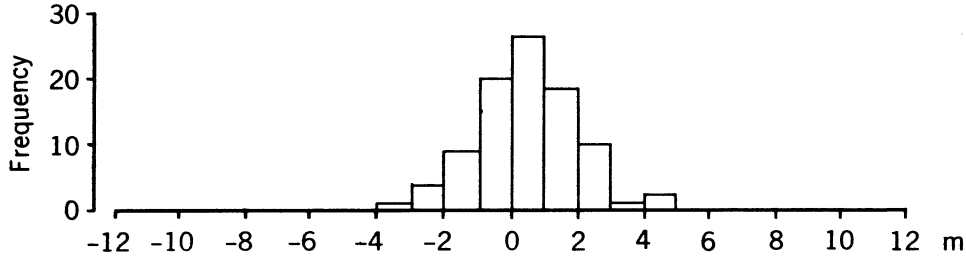

Figure 11.9c. AGD 84 - Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using AGD 84-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) in the Molodensky Datum Transformation Formulas.

SECTION 12

NON-DOPPLER DERIVED
DATUM TRANSFORMATION PARAMETERS
- LOCAL GEODETIC SYSTEMS TO WGS 84 -

Table 12.1

Non-Doppler Derived Datum Transformation Parameters
- Local Geodetic Systems to WGS 84 -

Local Geodetic Systems	Reference Ellipsoids and Parameter Differences*			Transformation Parameters*		
	Name	Δa (m)	$\Delta f \times 10^4$	ΔX(m)	ΔY(m)	ΔZ(m)
BUKIT RIMPAH Bangka and Belitung Islands (Indonesia)	Bessel 1841	739.845	0.10037483	-384	664	-48
CAMP AREA ASTRO Camp McMurdo Area, Antarctica	International	-251	-0.14192702	-104	-129	239
G. SEGARA Kalimantan Island (Indonesia)	Bessel 1841	739.845	0.10037483	-403	684	41
HERAT NORTH Afghanistan	International	-251	-0.14192702	-333	-222	114
HU-TZU-SHAN Taiwan	International	-251	-0.14192702	-634	-549	-201
TANANARIVE OBSERVATORY 1925 Madagascar	International	-251	-0.14192702	-189	-242	-91
YACARE Uruguay	International	-251	-0.14192702	-155	171	37

* WGS 84 minus local geodetic system

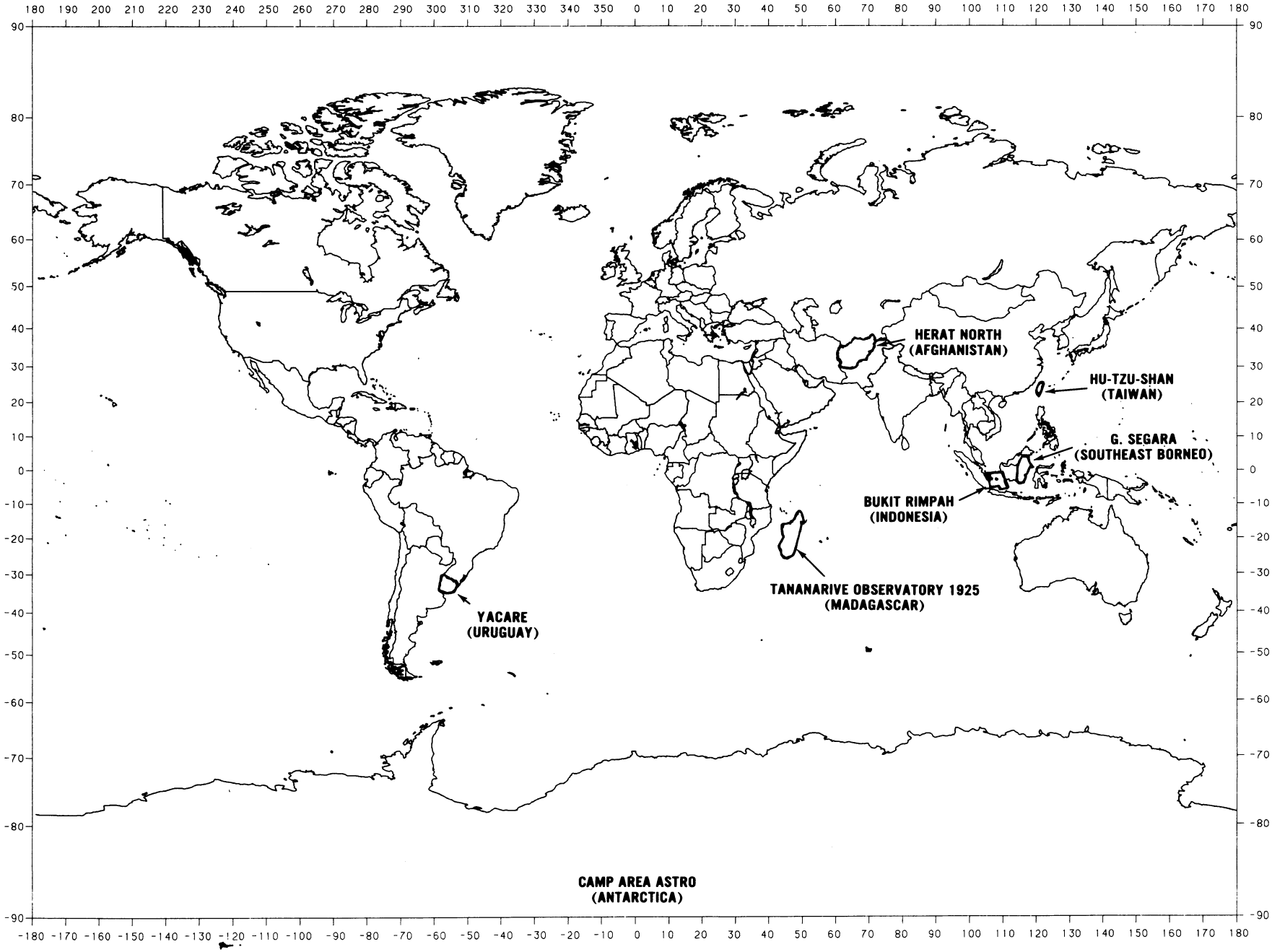

Figure 12.1. Local Geodetic Systems (Table 12.1) Related to WGS 84 Using Non-Doppler Derived Local Geodetic System-to-WGS 84 Datum Transformation Parameters

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SECTION 13

LOCAL GEODETIC SYSTEM-TO-WGS 84 DATUM SHIFTS

- ΔX, ΔY, ΔZ CONTOUR CHARTS FOR MAJOR DATUMS - *

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* THE ΔX, ΔY, ΔZ VALUES MAY BE USED IN THE MOLODENSKY DATUM TRANSFORMATION FORMULAS (TABLE 6.4), OR IN THE FORMULAS:

$$X_{WGS\ 84} = X_{LGS} + \Delta X$$

$$Y_{WGS\ 84} = Y_{LGS} + \Delta Y$$

$$Z_{WGS\ 84} = Z_{LGS} + \Delta Z$$

[LGS = LOCAL GEODETIC SYSTEM]

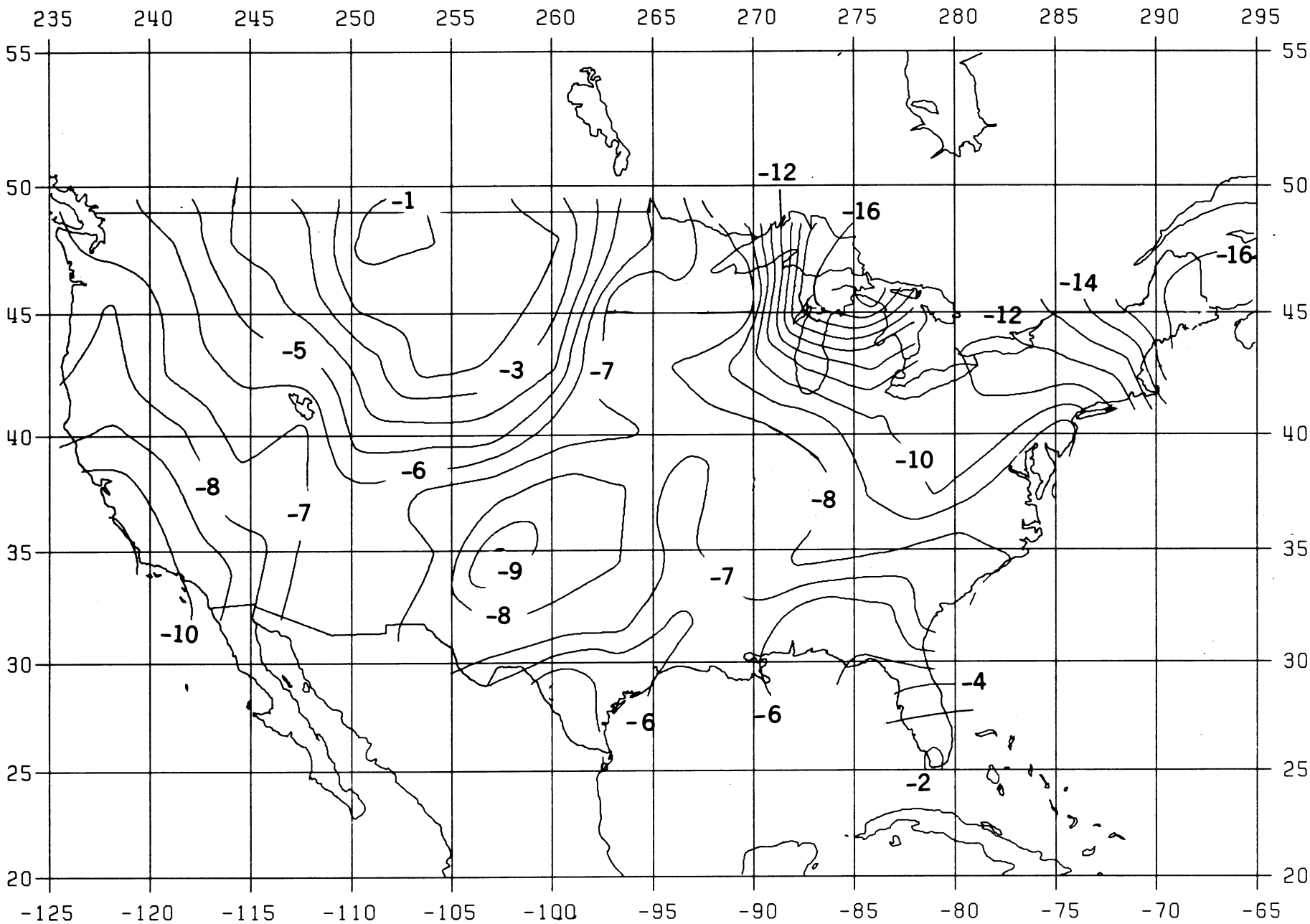

Figure 13.1. Contour Chart–NAD 27 to WGS 84 Datum Shifts (CONUS), ΔX Component (Contour Interval = 1 Meter)

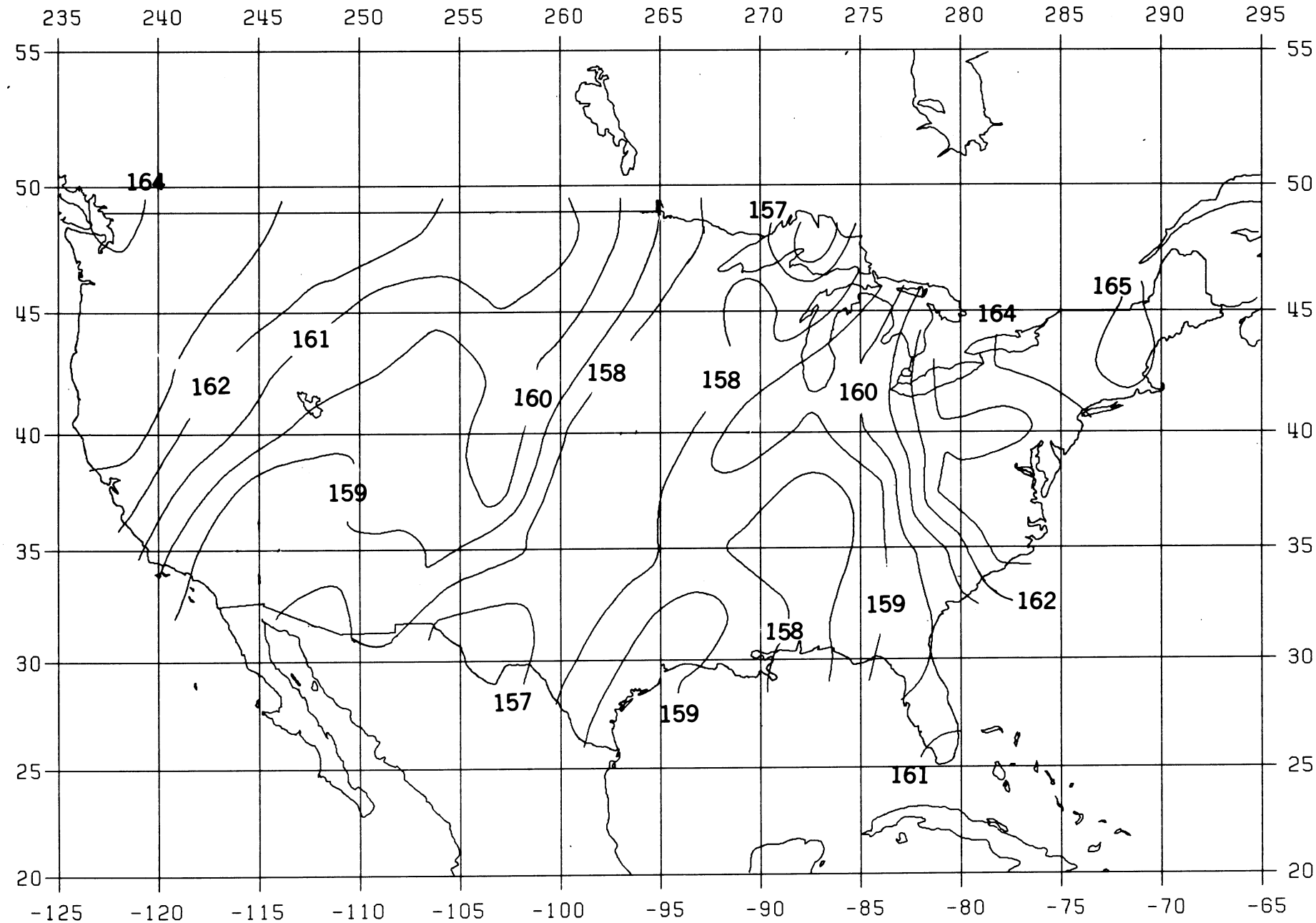

Figure 13.2. Contour Chart–NAD 27 to WGS 84 Datum Shifts (CONUS), ΔY Component (Contour Interval = 1 Meter)

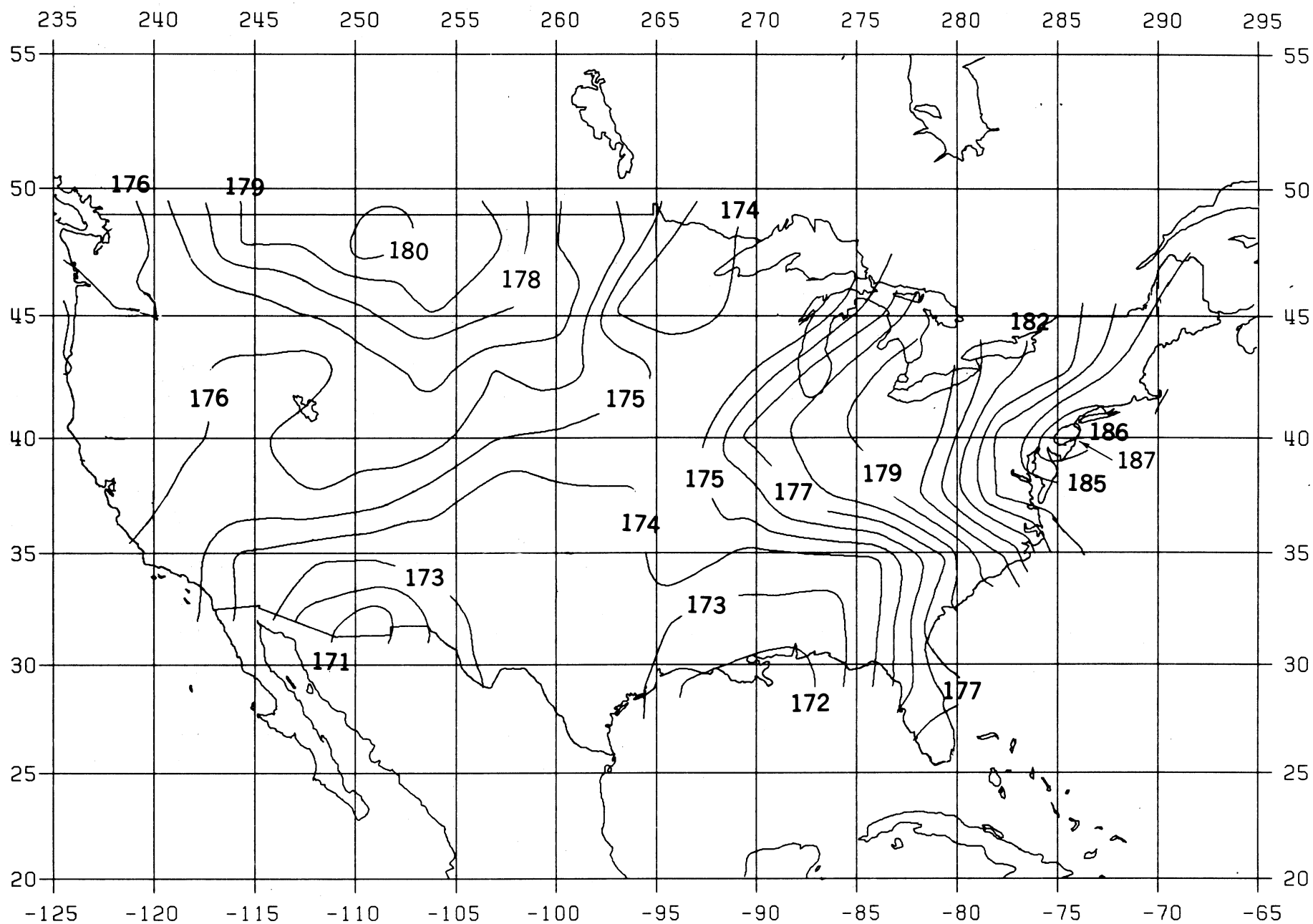

Figure 13.3. Contour Chart–NAD 27 to WGS 84 Datum Shifts (CONUS), ΔZ Component (Contour Interval = 1 Meter)

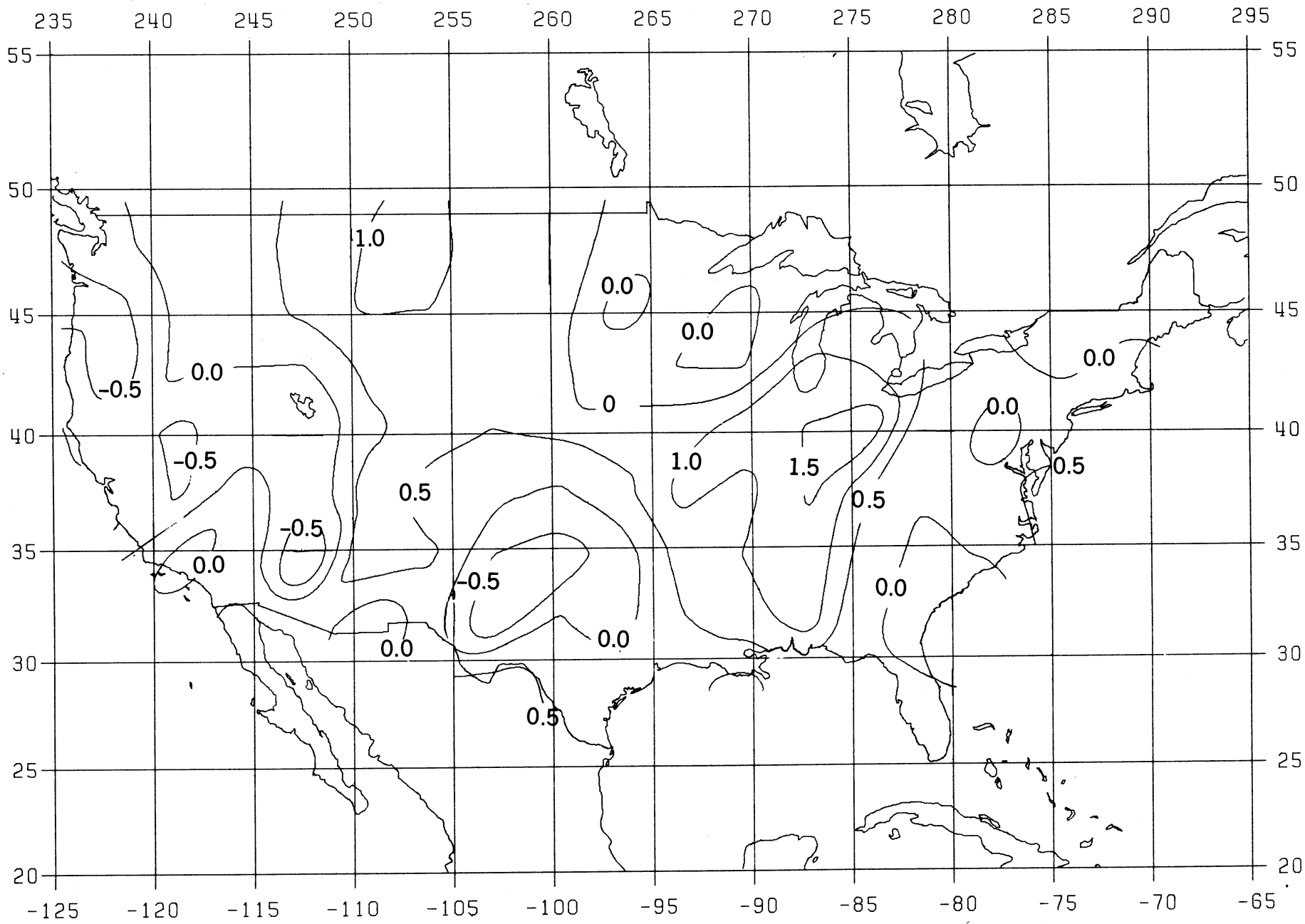

Figure 13.4. Contour Chart – NAD 83 to WGS 84 Datum Shifts (CONUS), ΔX Component (Contour Interval = 0.5 Meter)

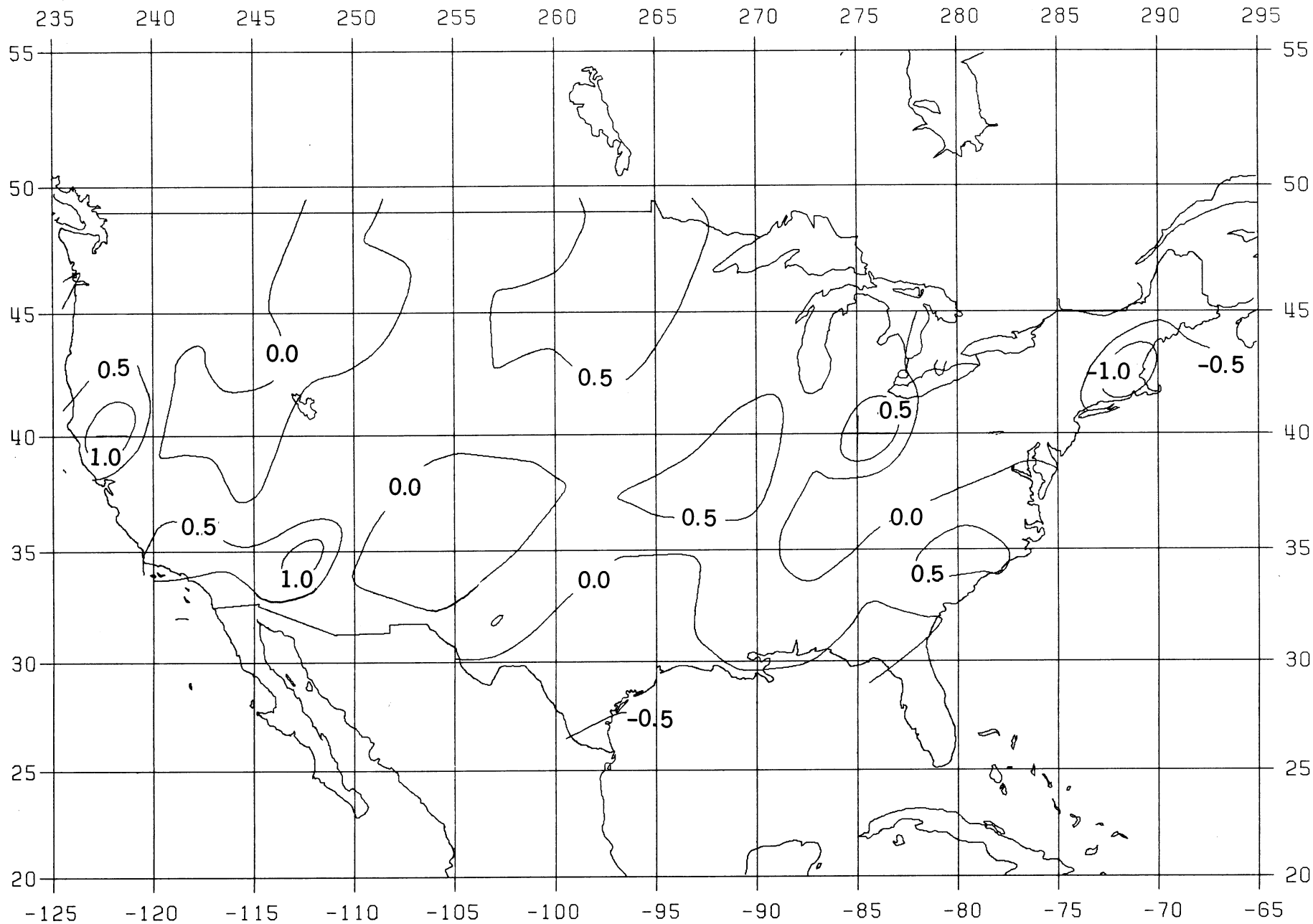

Figure 13.5. Contour Chart - NAD 83 to WGS 84 Datum Shifts (CONUS), ΔY Component (Contour Interval = 0.5 Meter)

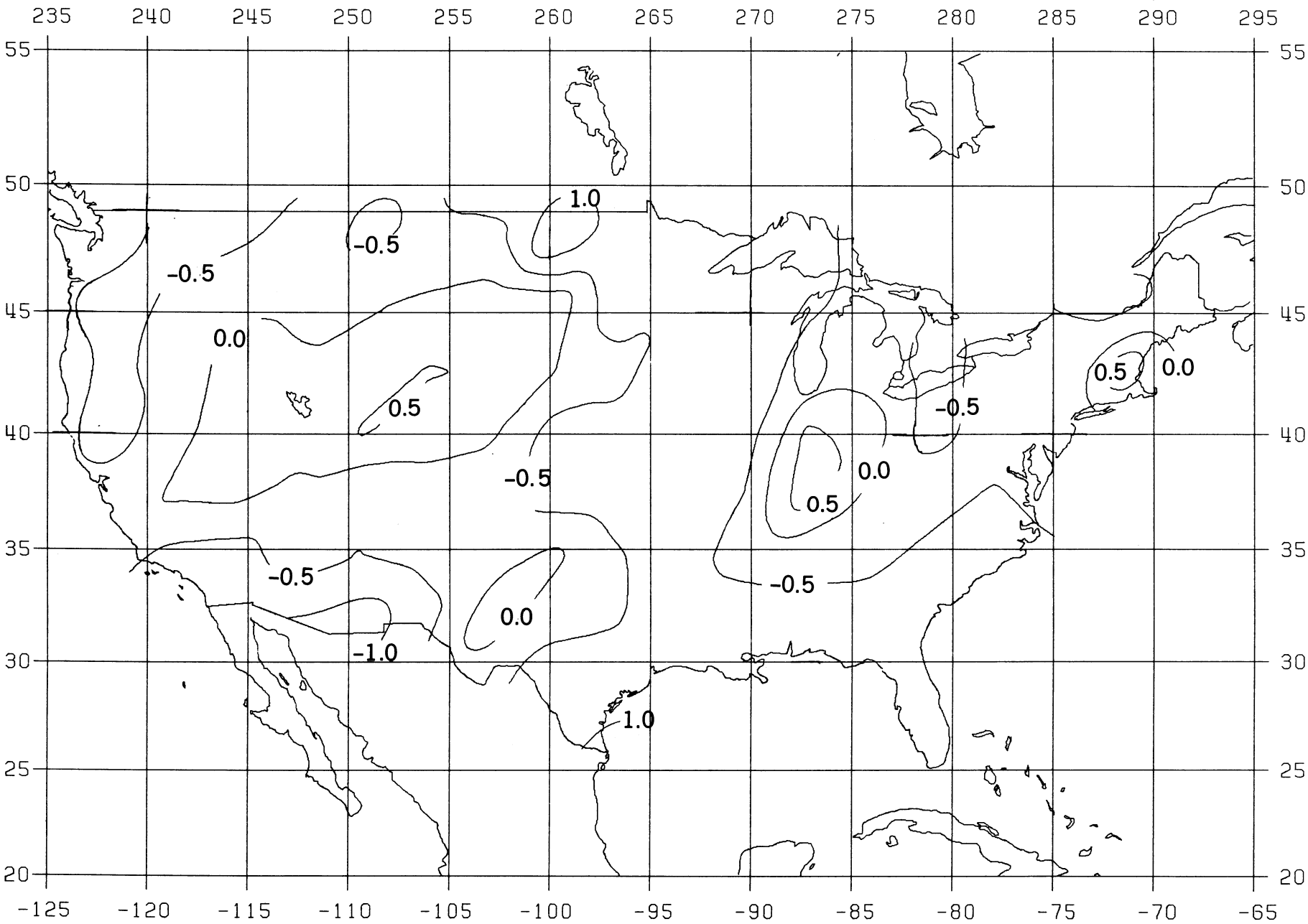

Figure 13.6. Contour Chart - NAD 83 to WGS 84 Datum Shifts (CONUS), ΔZ Component (Contour Interval = 0.5 Meter)

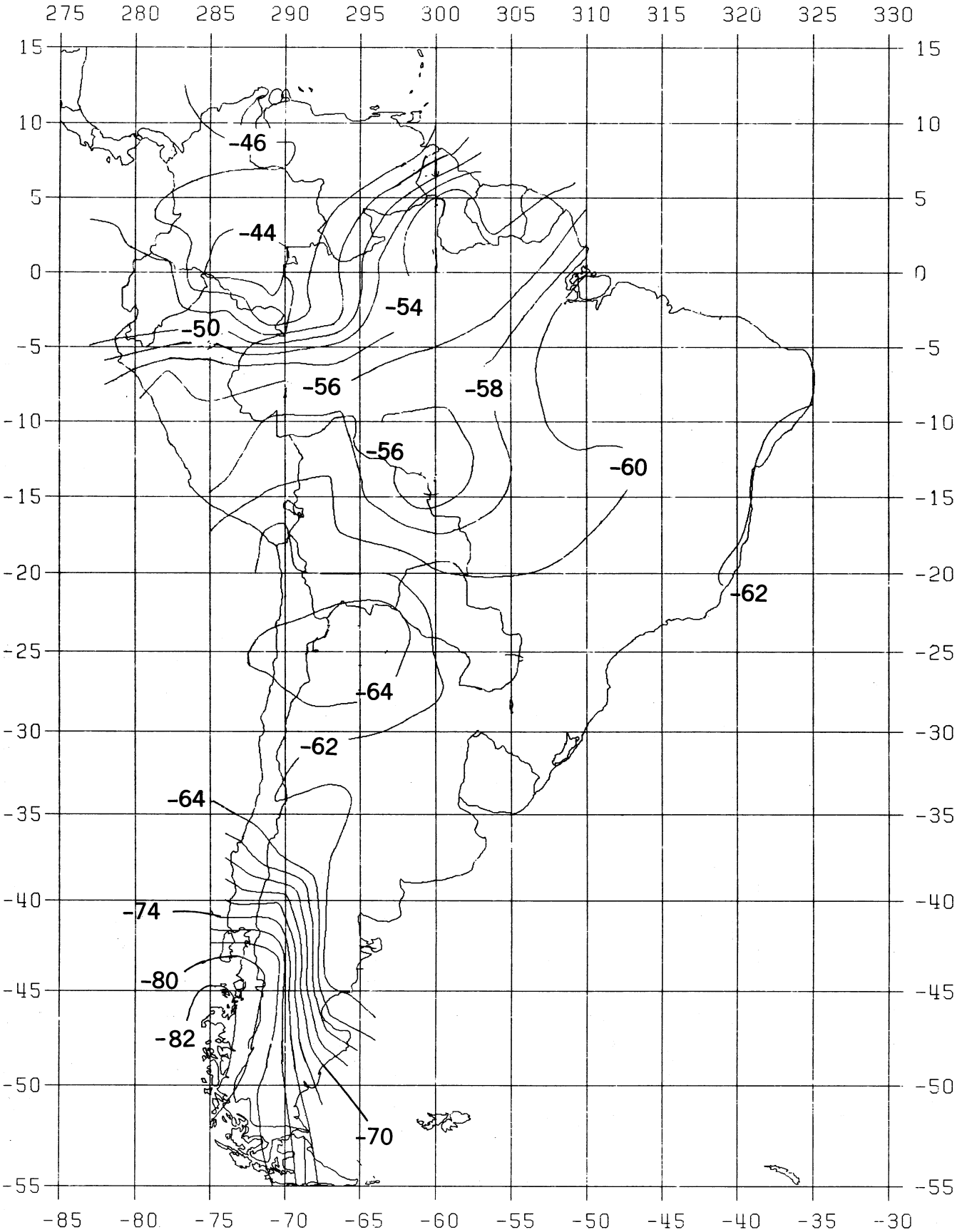

Figure 13.7. Contour Chart - SAD 69 to WGS 84 Datum Shifts, ΔX Component
(Contour Interval = 2 Meters)

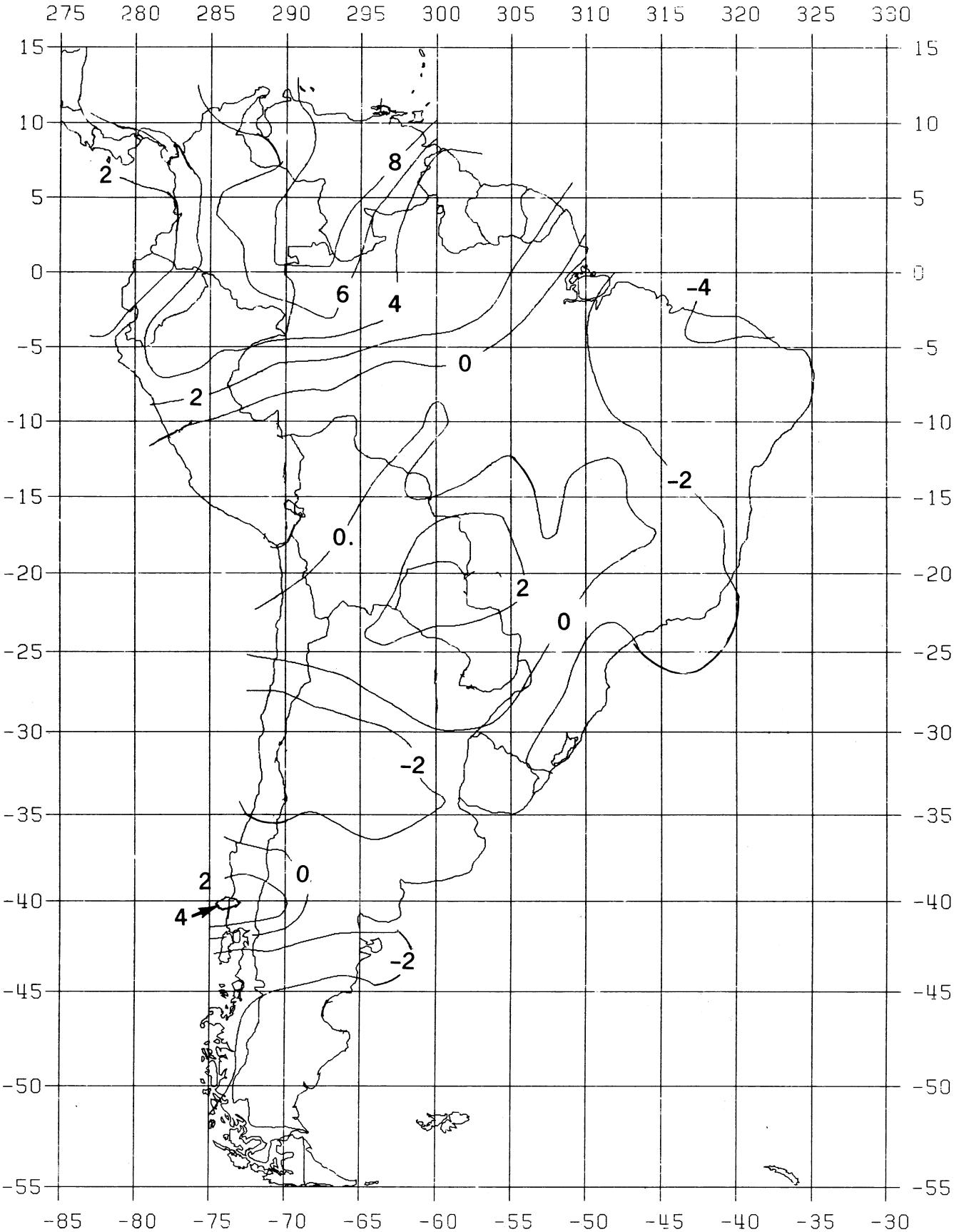

Figure 13.8. Contour Chart – SAD 69 to WGS 84 Datum Shifts, ΔY Component
(Contour Interval = 2 Meters)

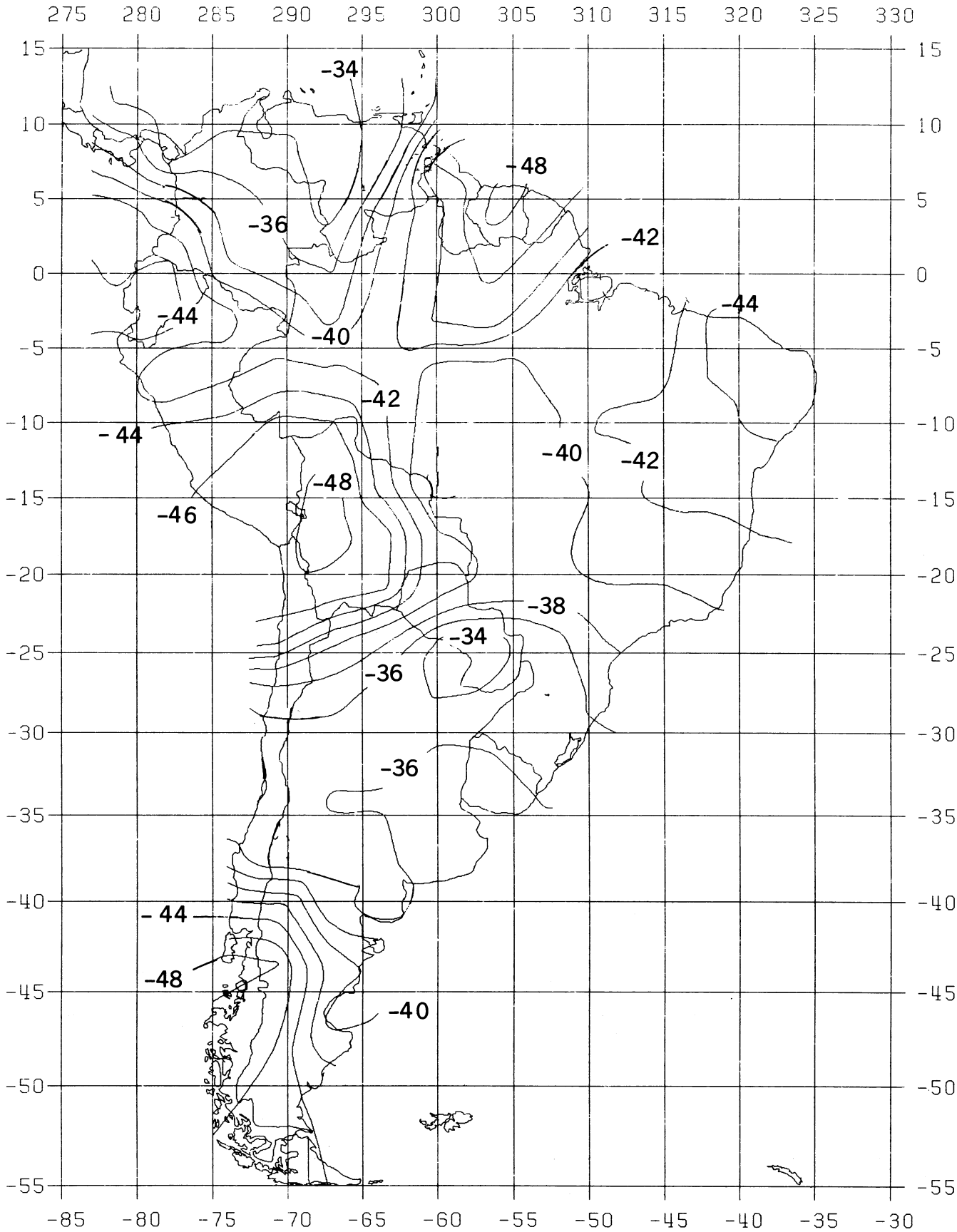

Figure 13.9. Contour Chart - SAD 69 to WGS 84 Datum Shifts, ΔZ Component
(Contour Interval = 2 Meters)

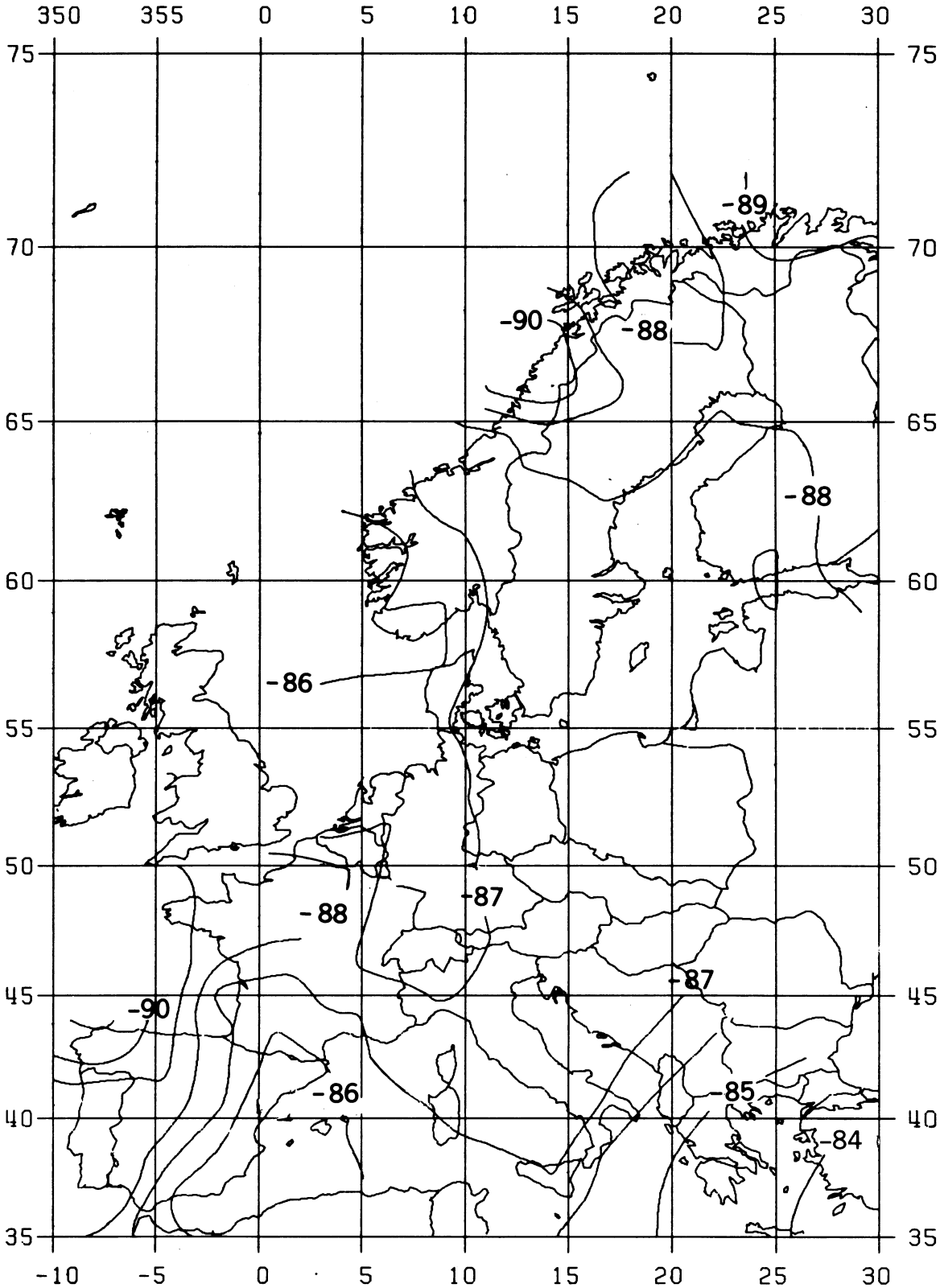

Figure 13.10. Contour Chart-ED 50 (Western Europe) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

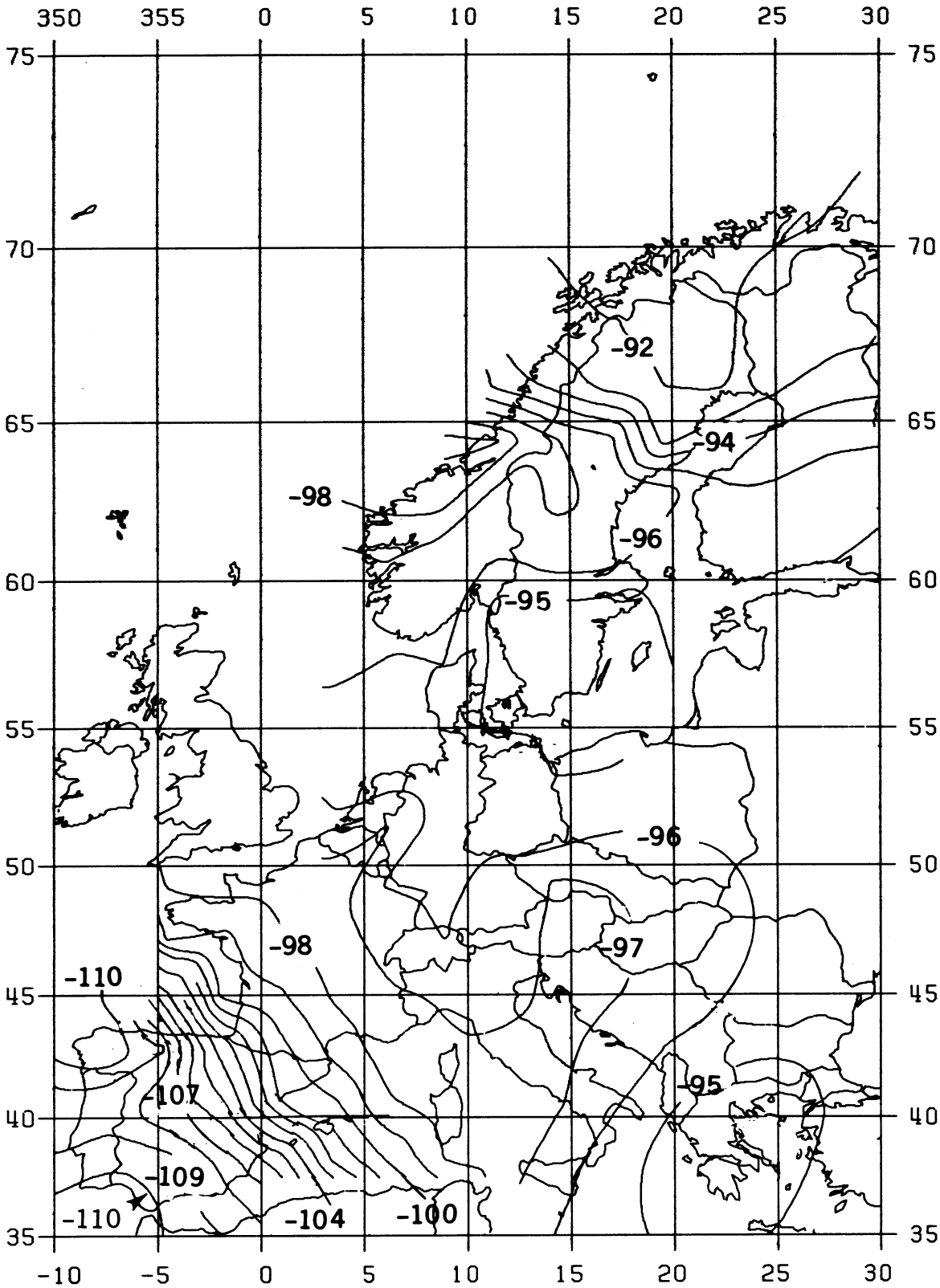

Figure 13.11. Contour Chart-ED 50 (Western Europe) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

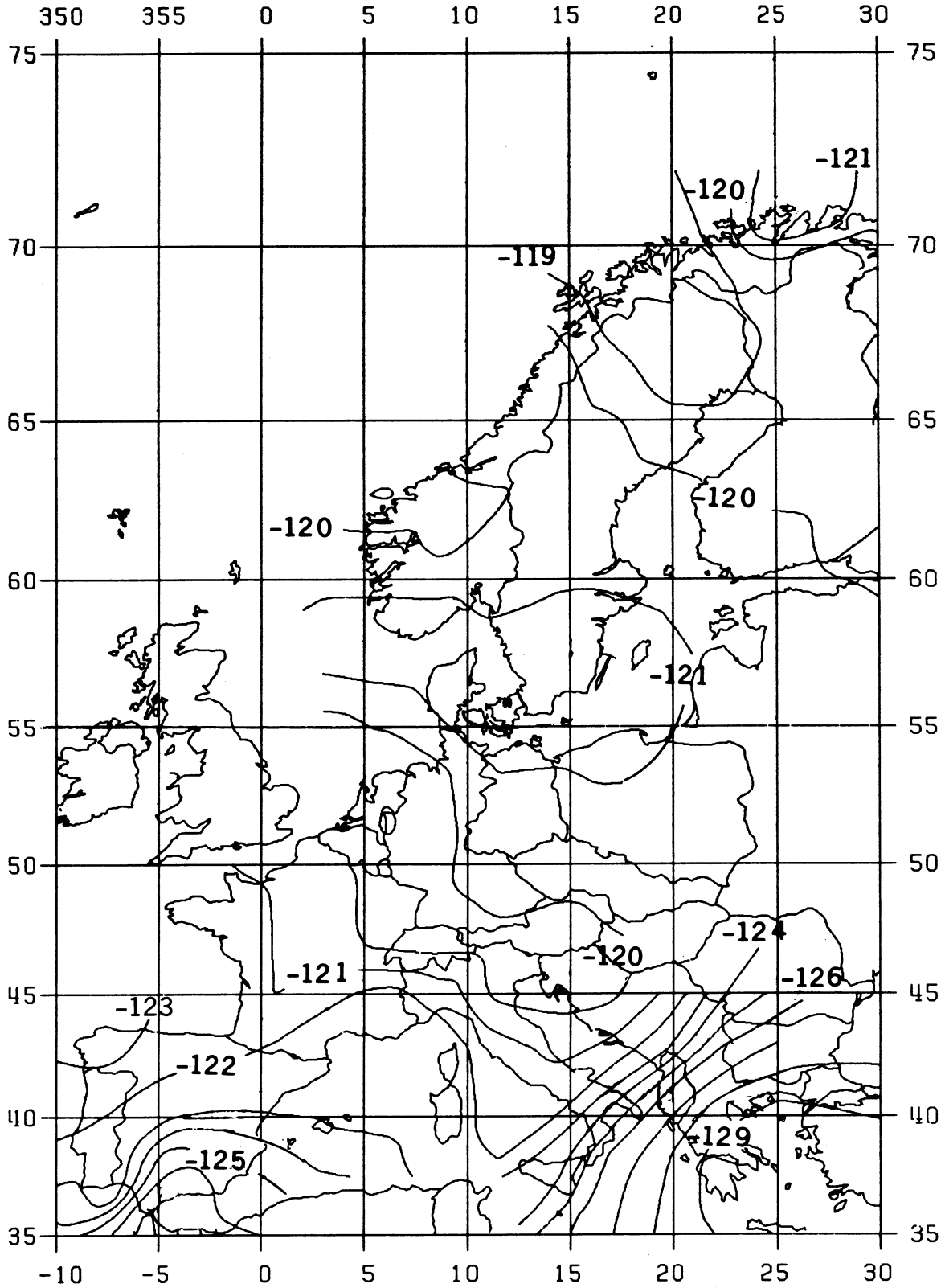

Figure 13.12. **Contour Chart–ED 50 (Western Europe) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)**

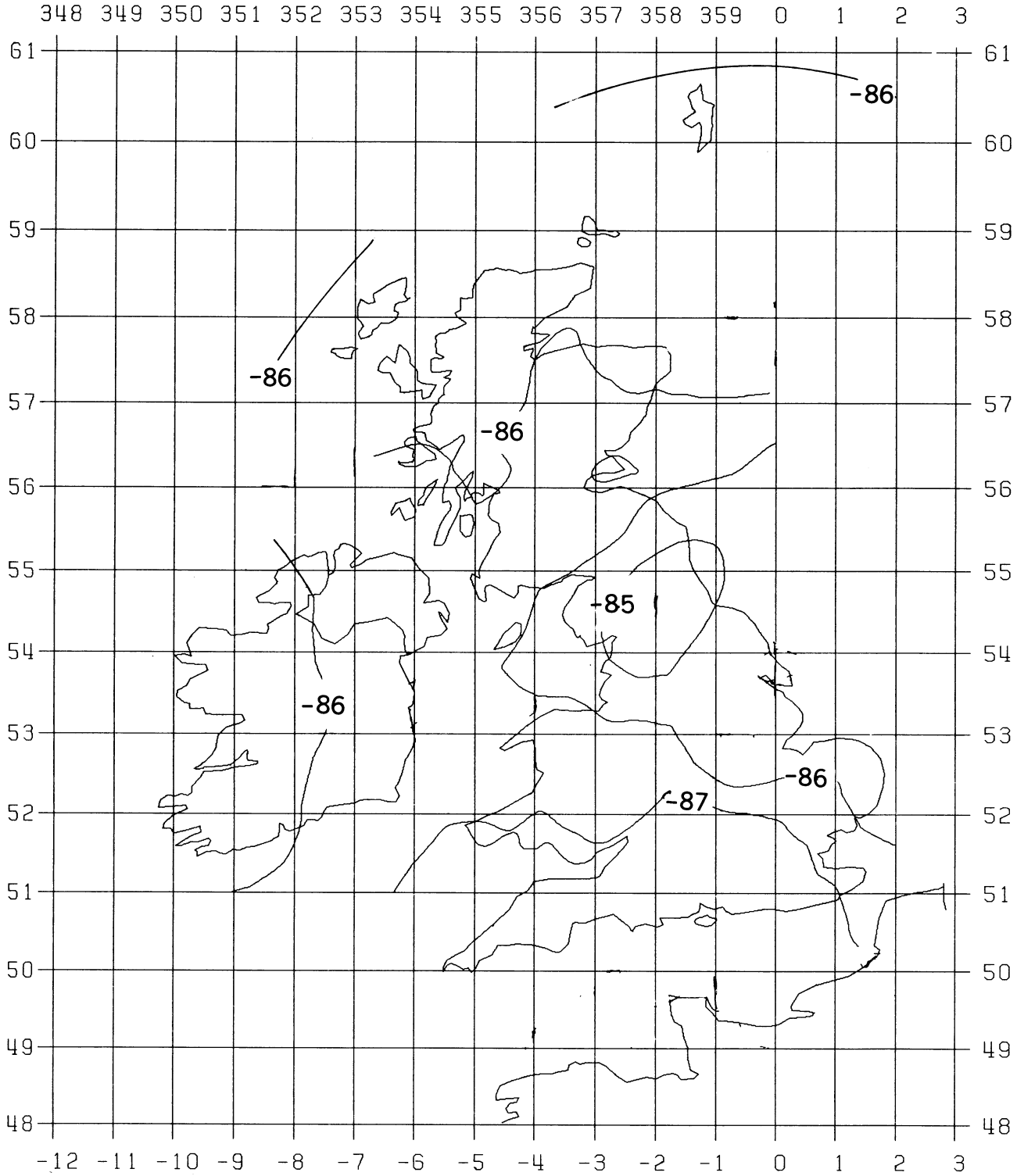

Figure 13.13. Contour Chart - ED 50 (UK/Ireland) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

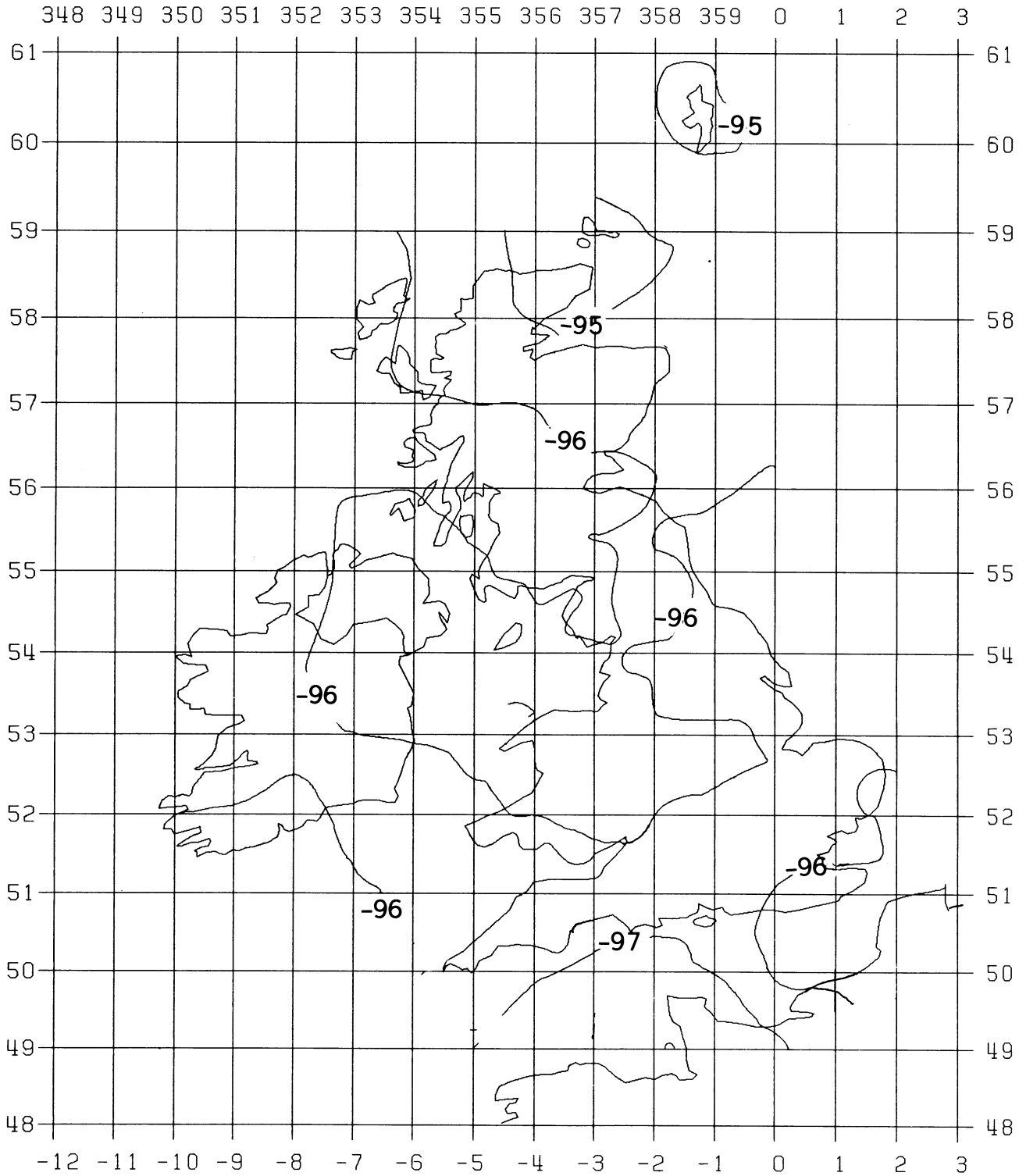

Figure 13.14. Contour Chart – ED 50 (UK/Ireland) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

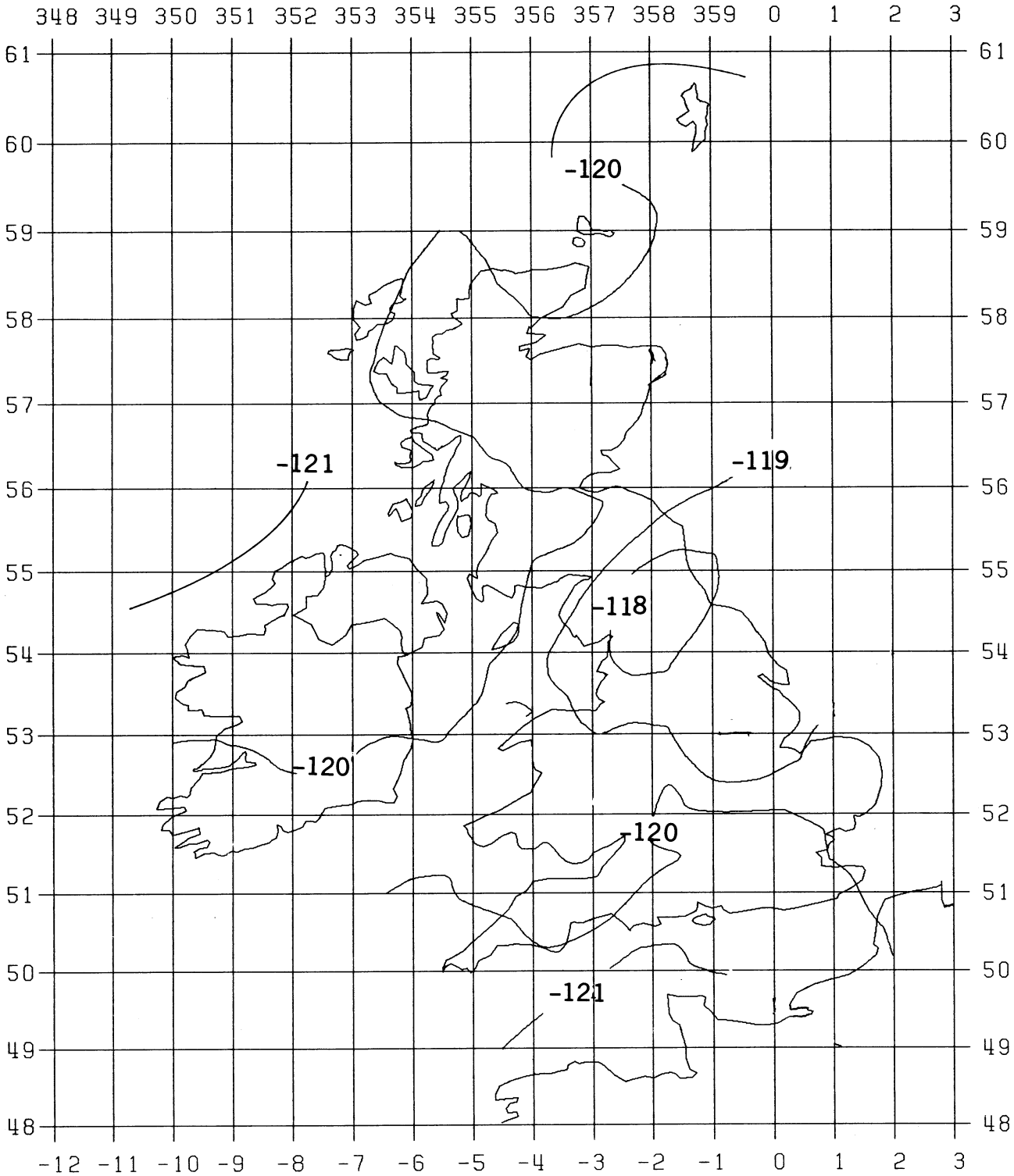

Figure 13.15. Contour Chart - ED 50 (UK/Ireland) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

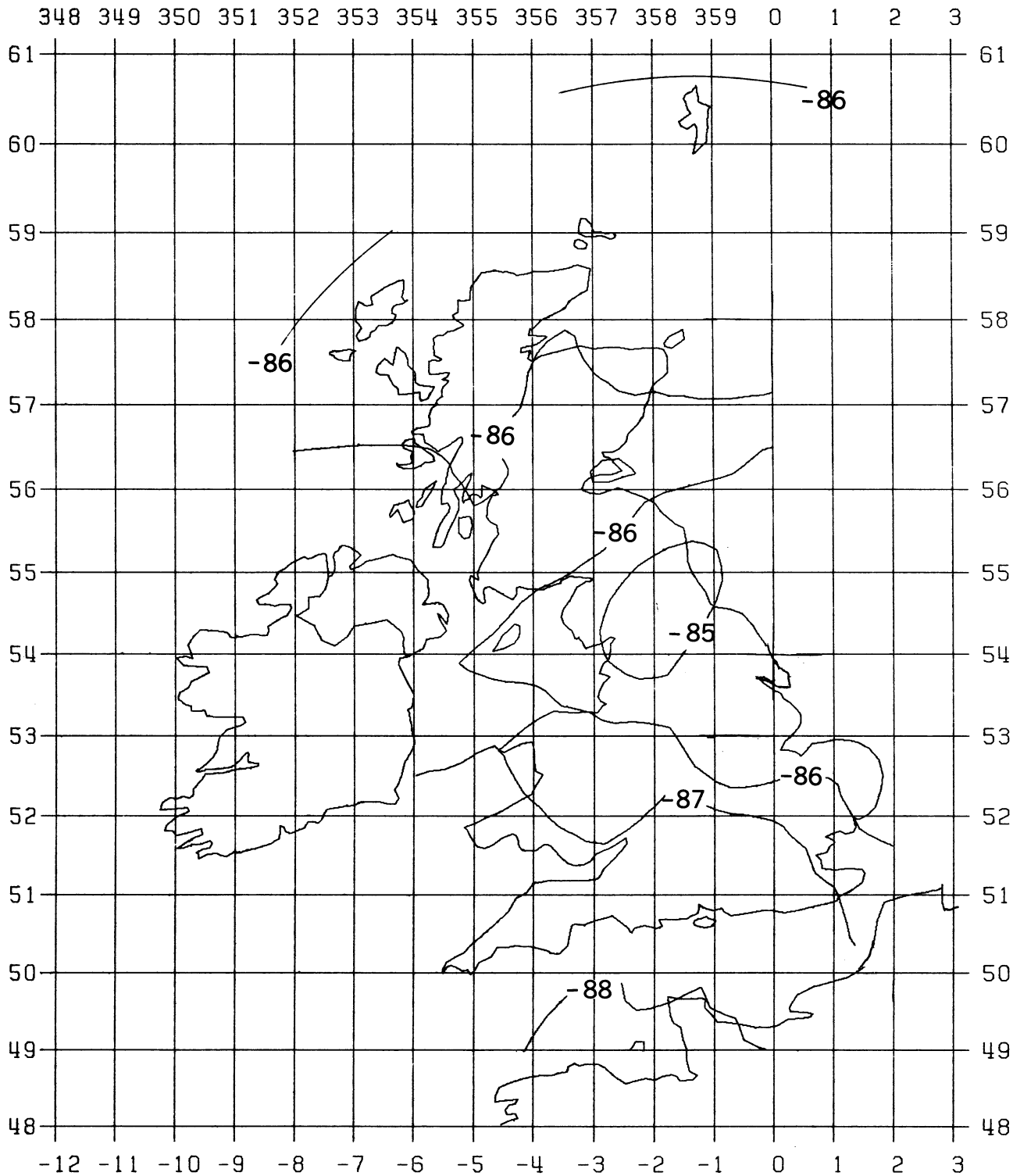

Figure 13.16. Contour Chart - ED 50 (UK Only) to WGS 84 Datum Shifts, △X Component (Contour Interval = 1 Meter)

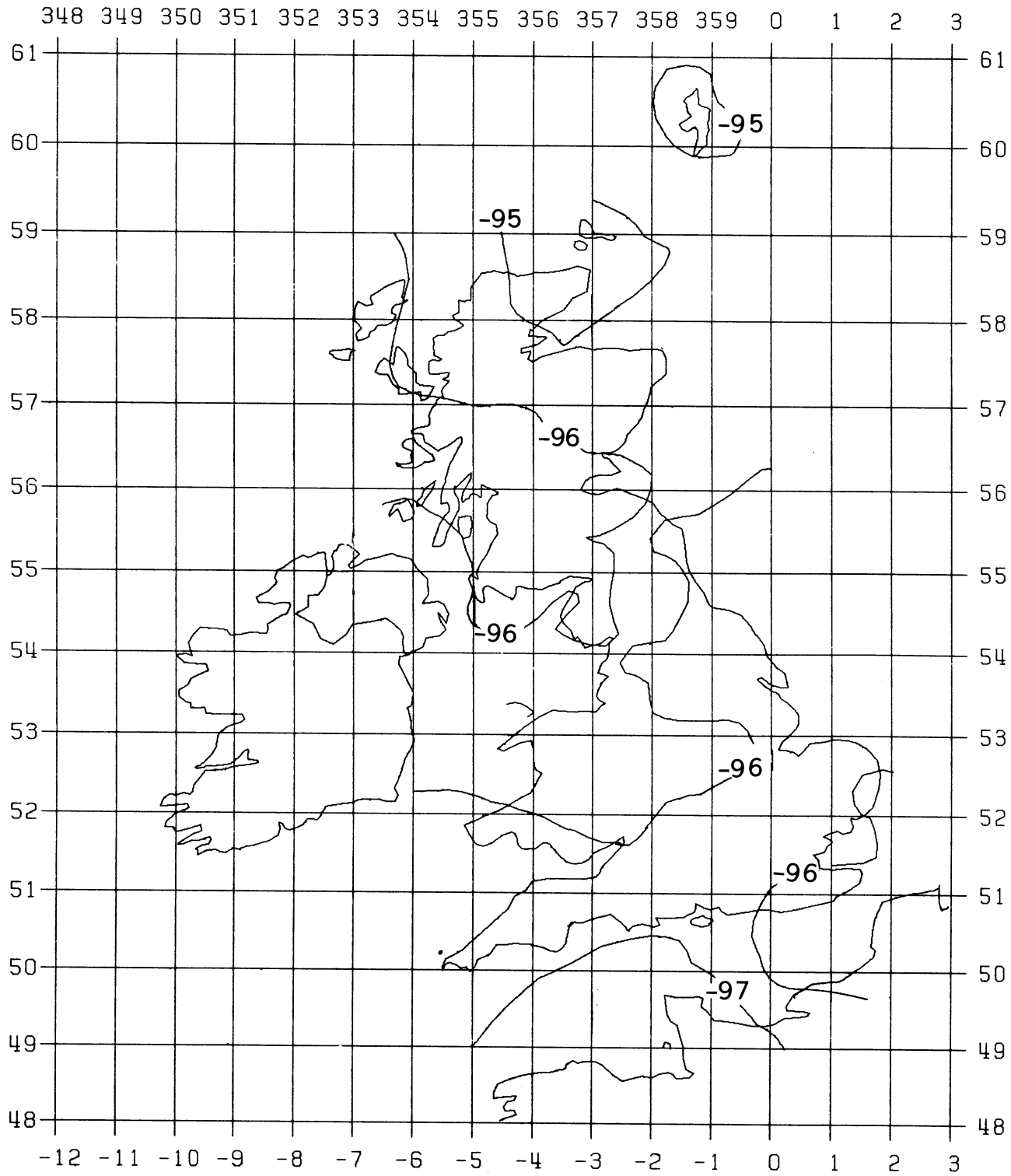

Figure 13.17. Contour Chart - ED 50 (UK Only) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

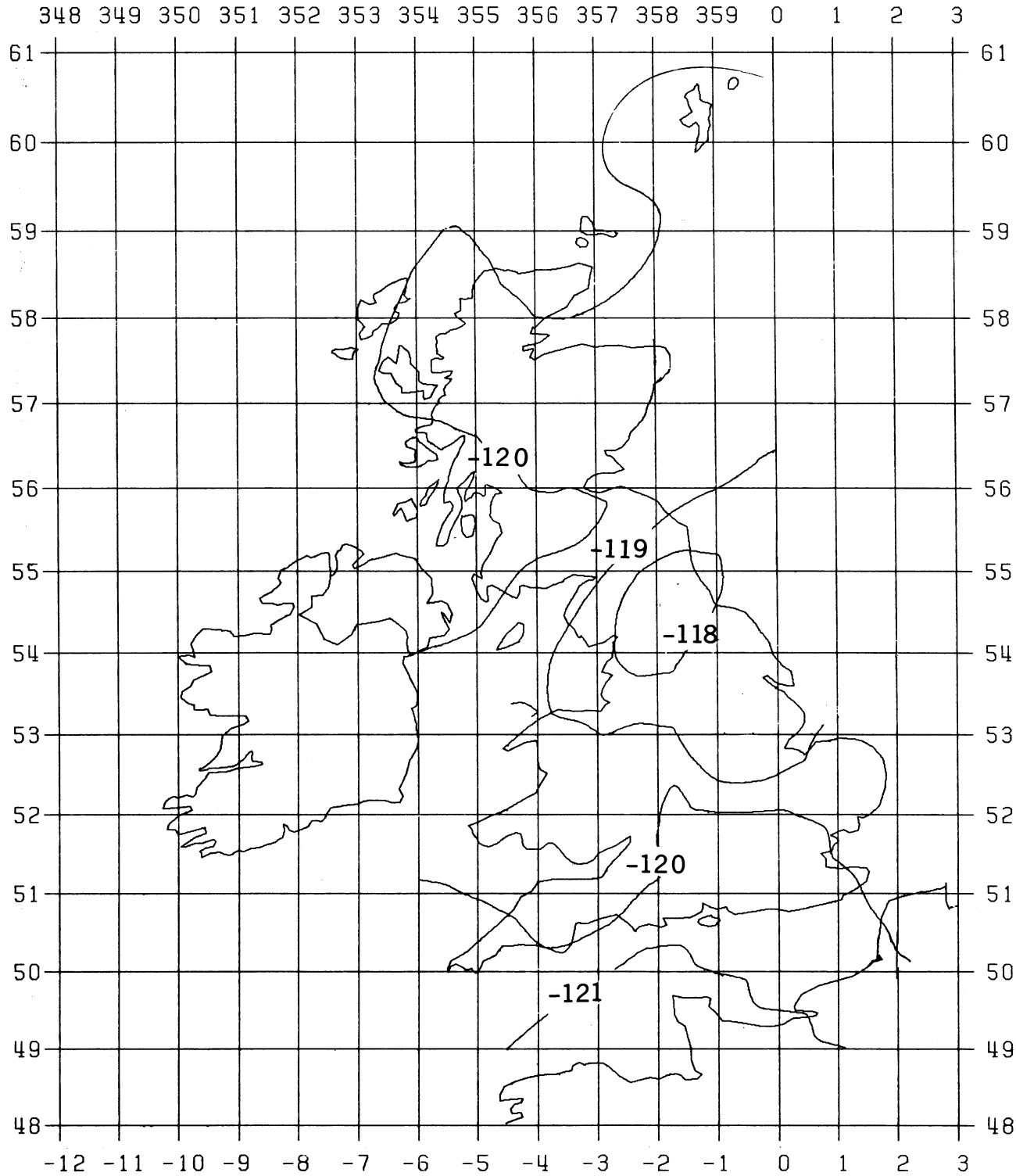

Figure 13.18. Contour Chart - ED 50 (UK Only) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

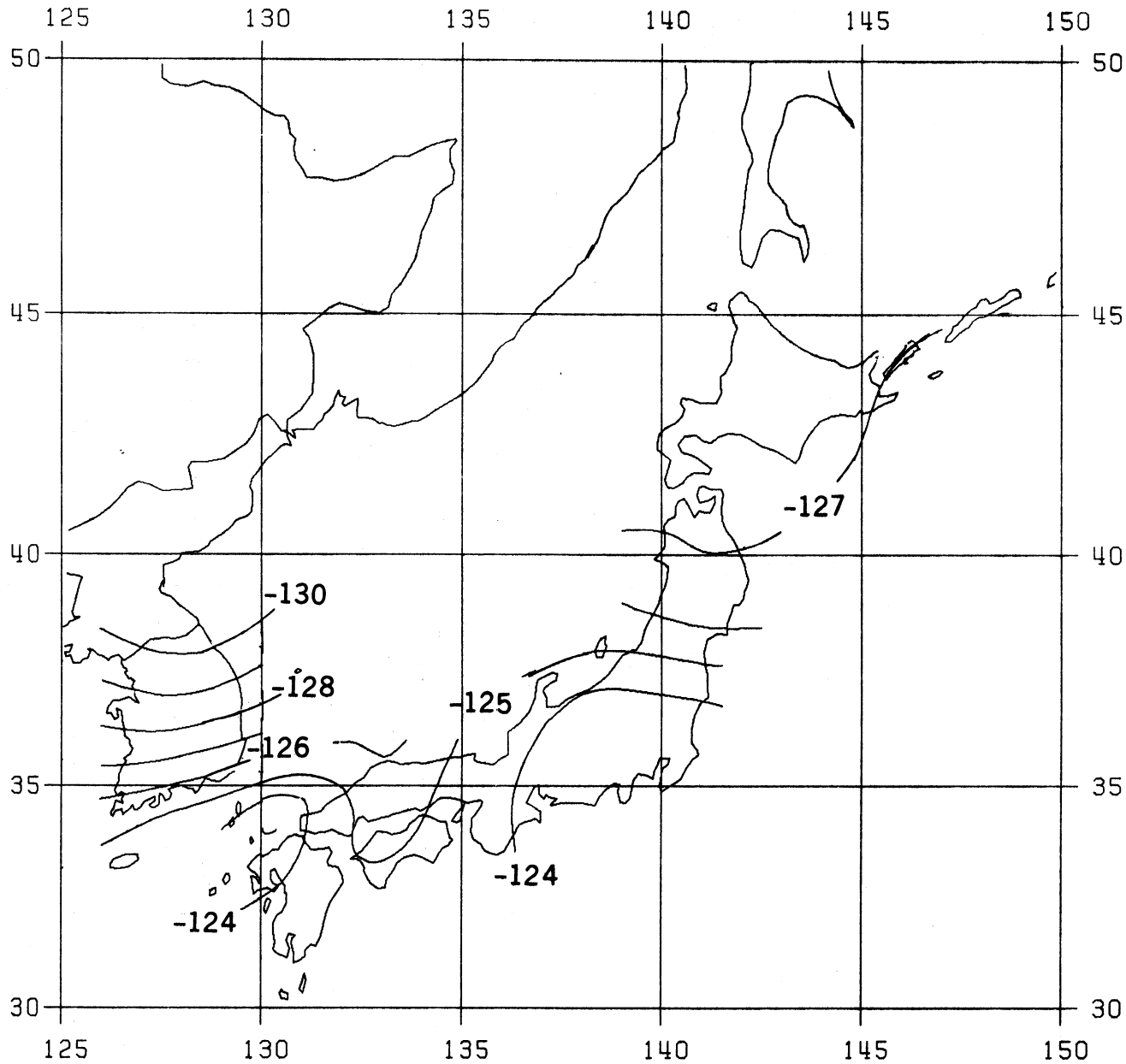

Figure 13.19. Contour Chart - TD to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

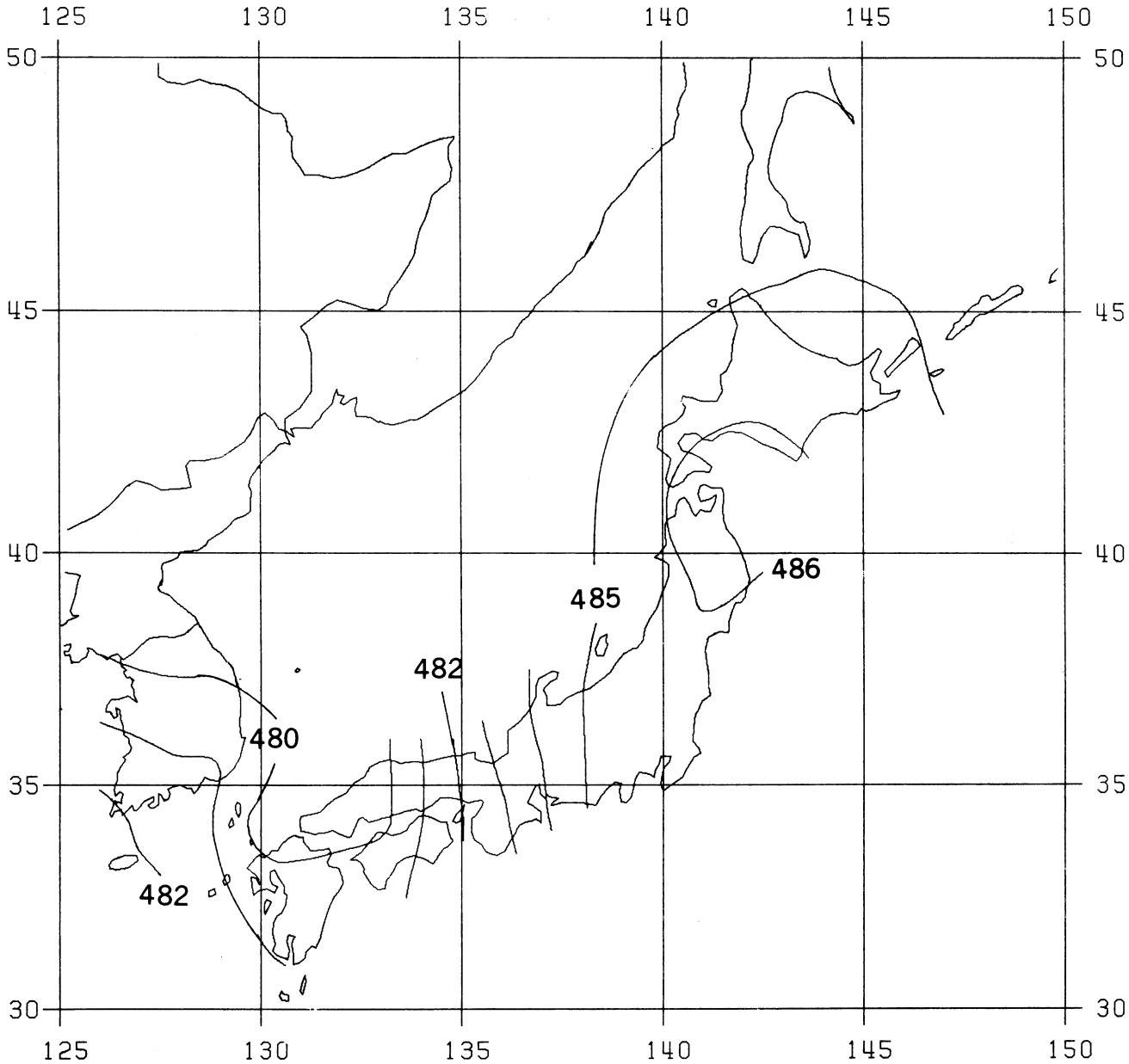

Figure 13.20. Contour Chart – TD to WGS 84 Datum Shifts, △Y Component (Contour Interval = 1 Meter)

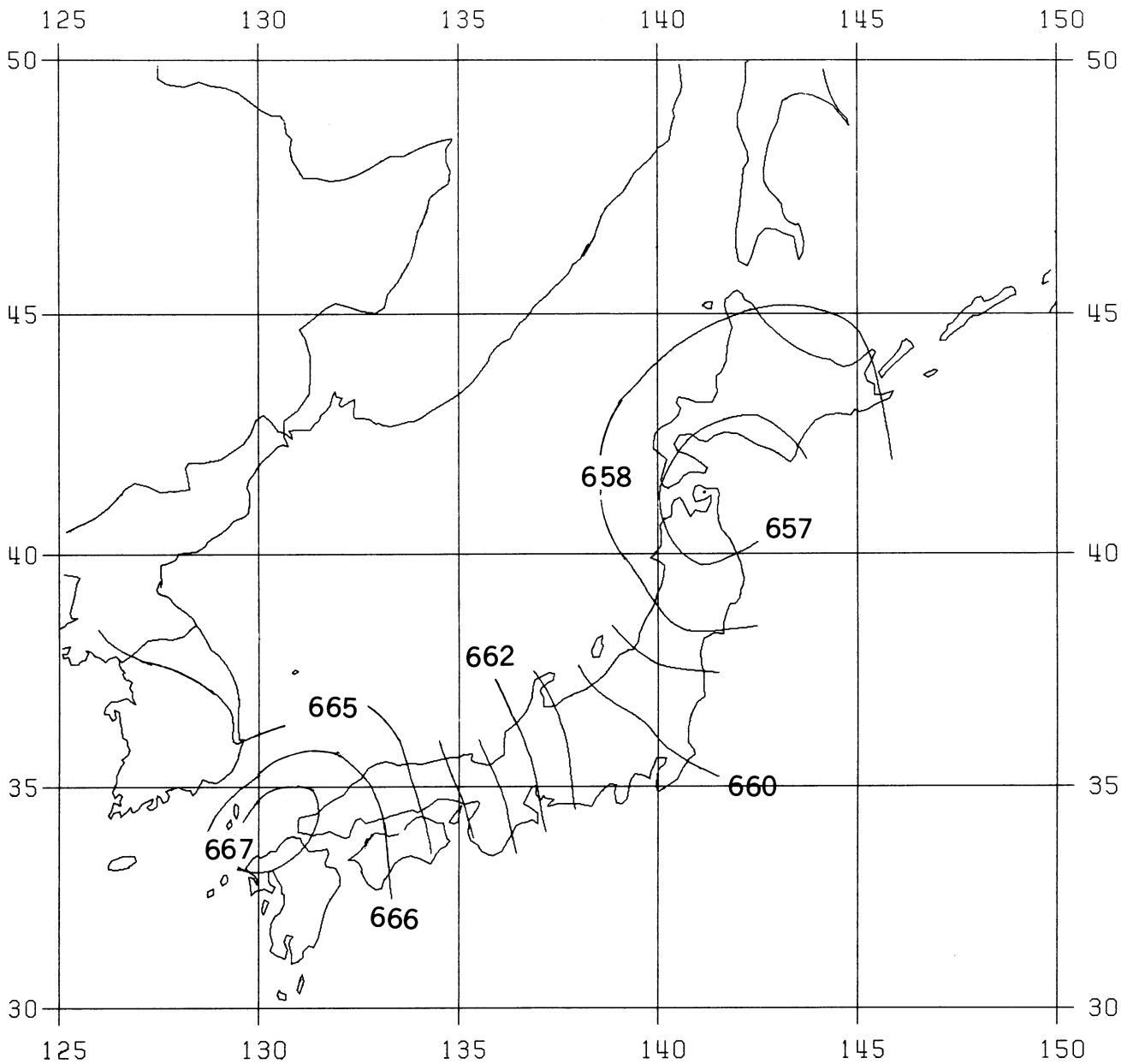

Figure 13.21. Contour Chart – TD to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

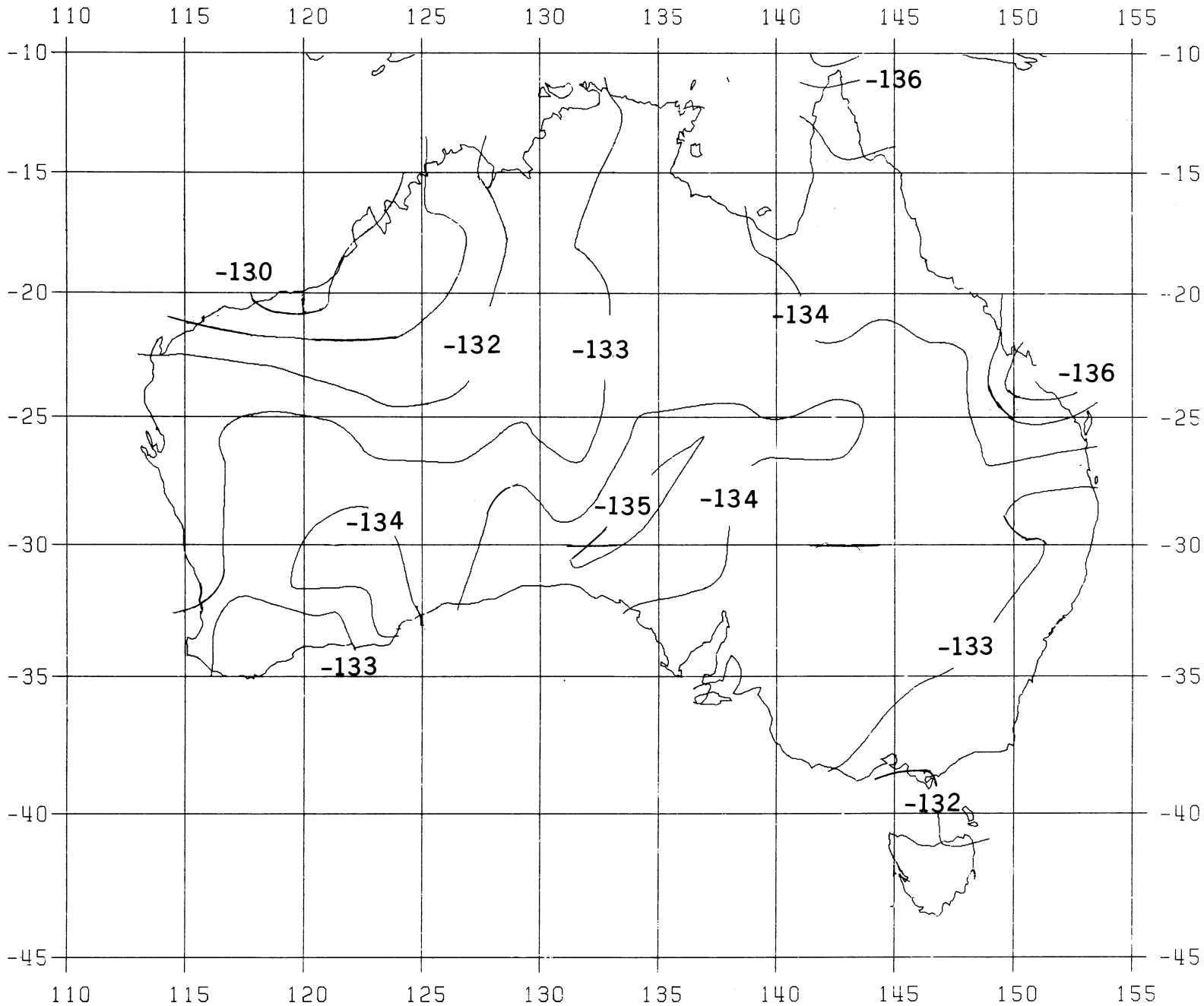

Figure 13.22. Contour Chart – AGD 66 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

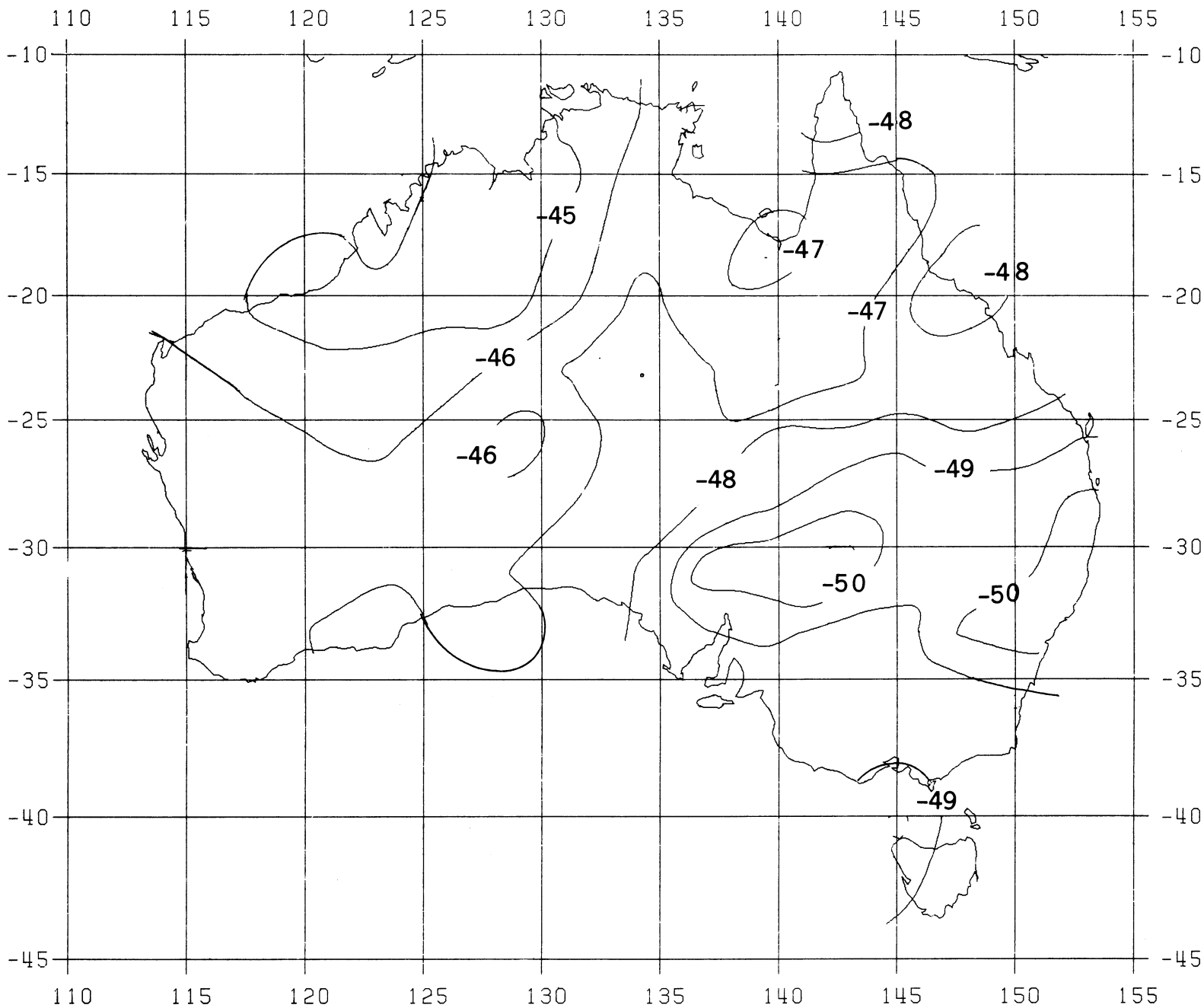

Figure 13.23. Contour Chart – AGD 66 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

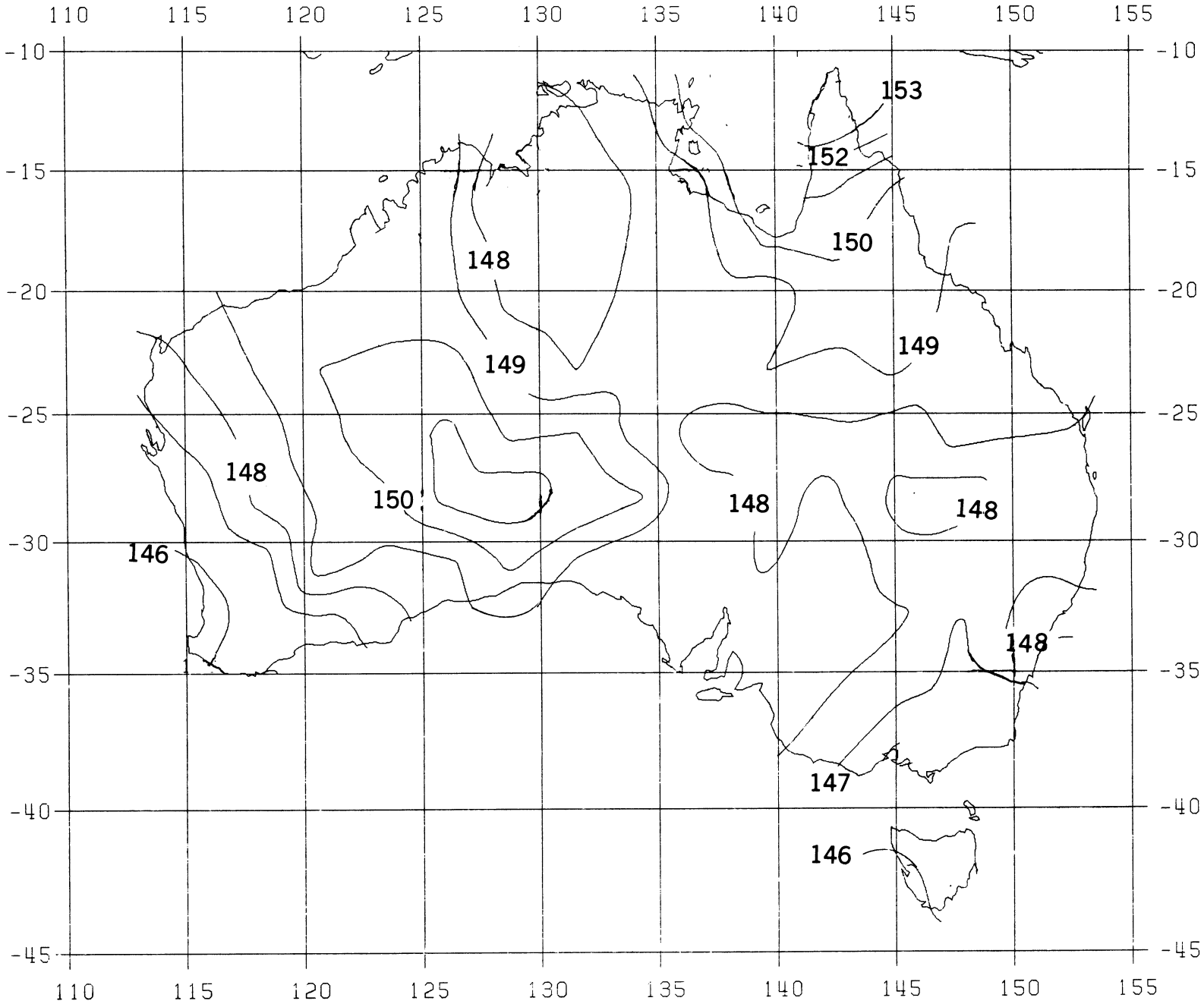

Figure 13.24. Contour Chart – AGD 66 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

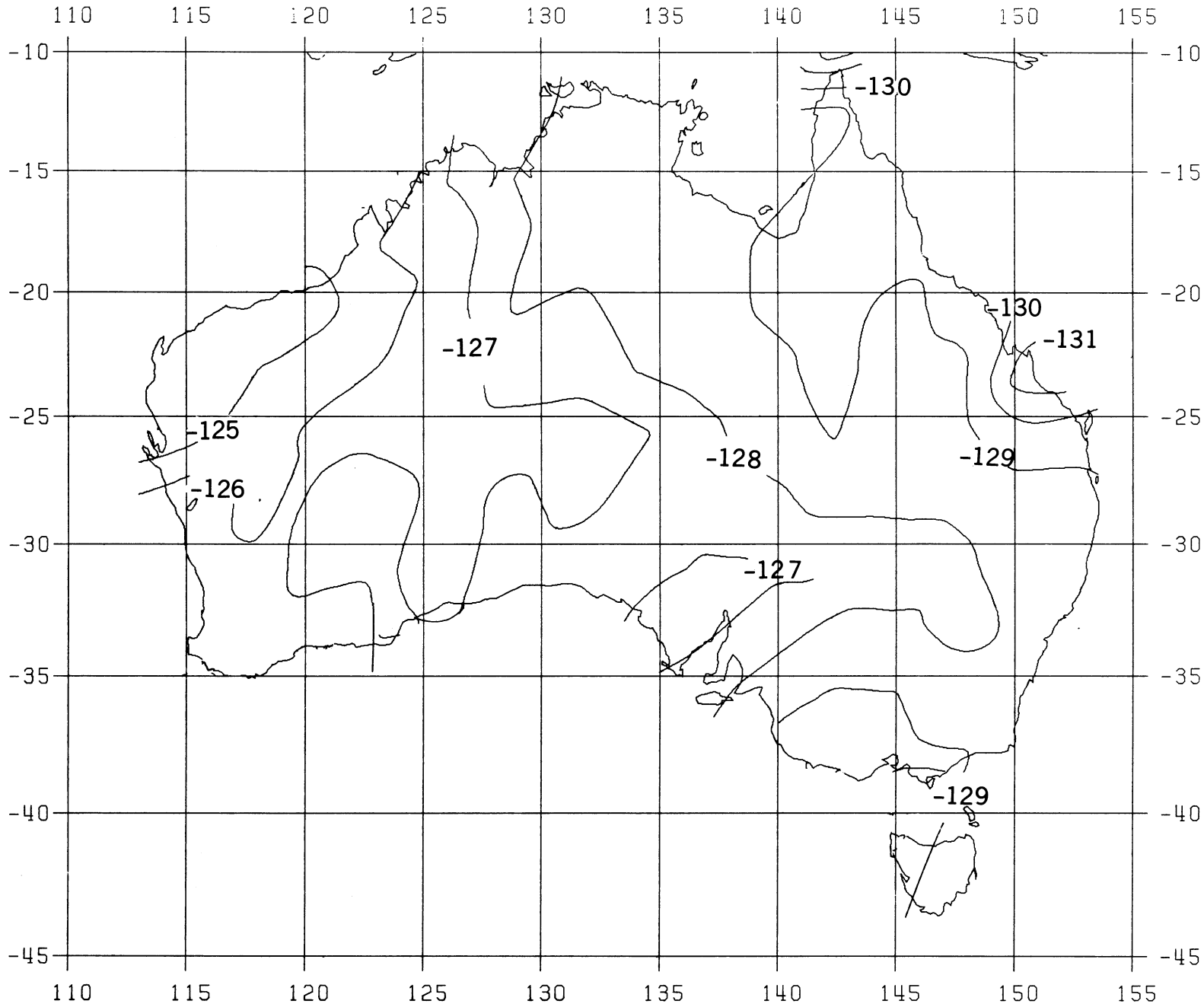

Figure 13.25. Contour Chart – AGD 84 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

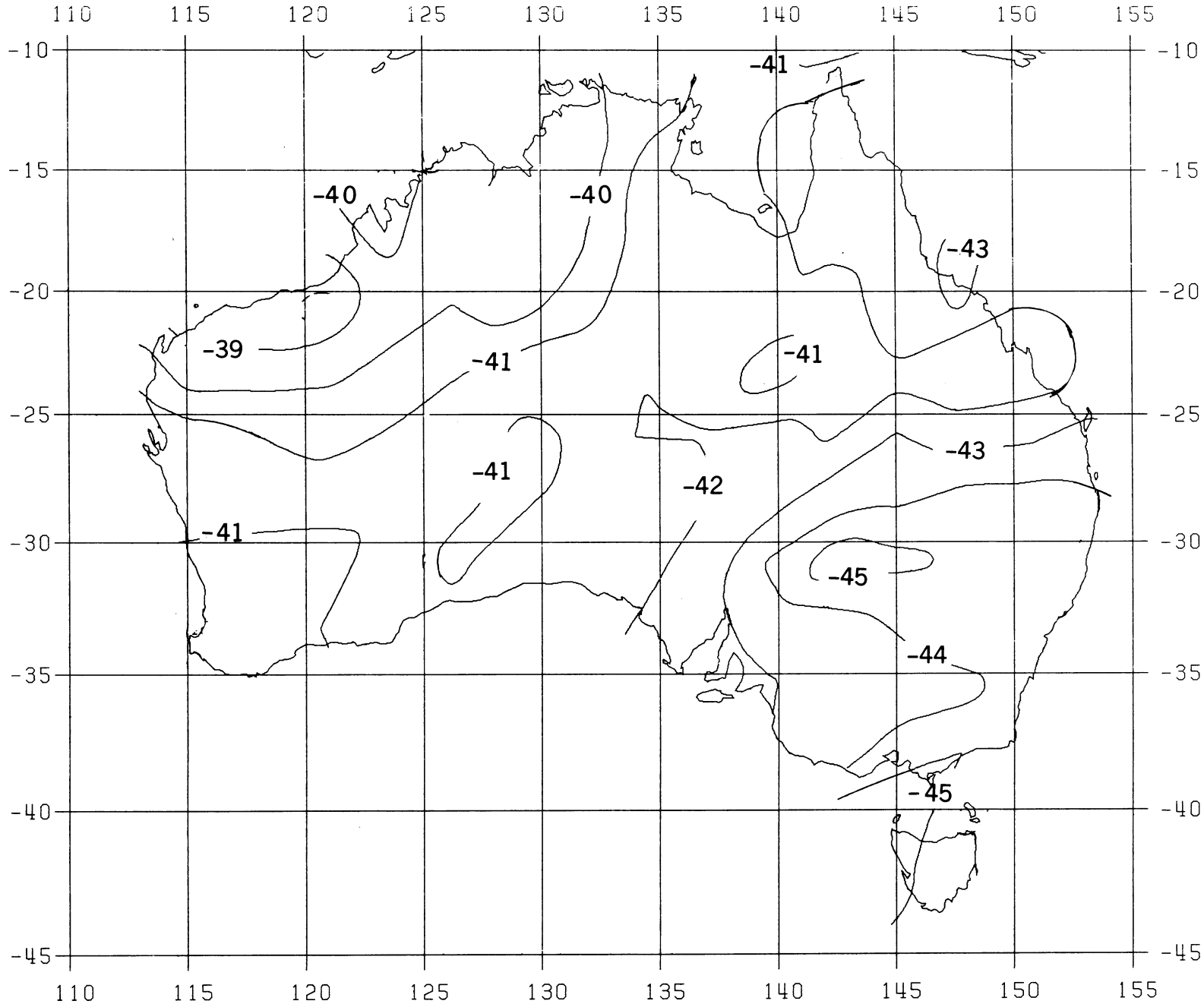

Figure 13.26. Contour Chart – AGD 84 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

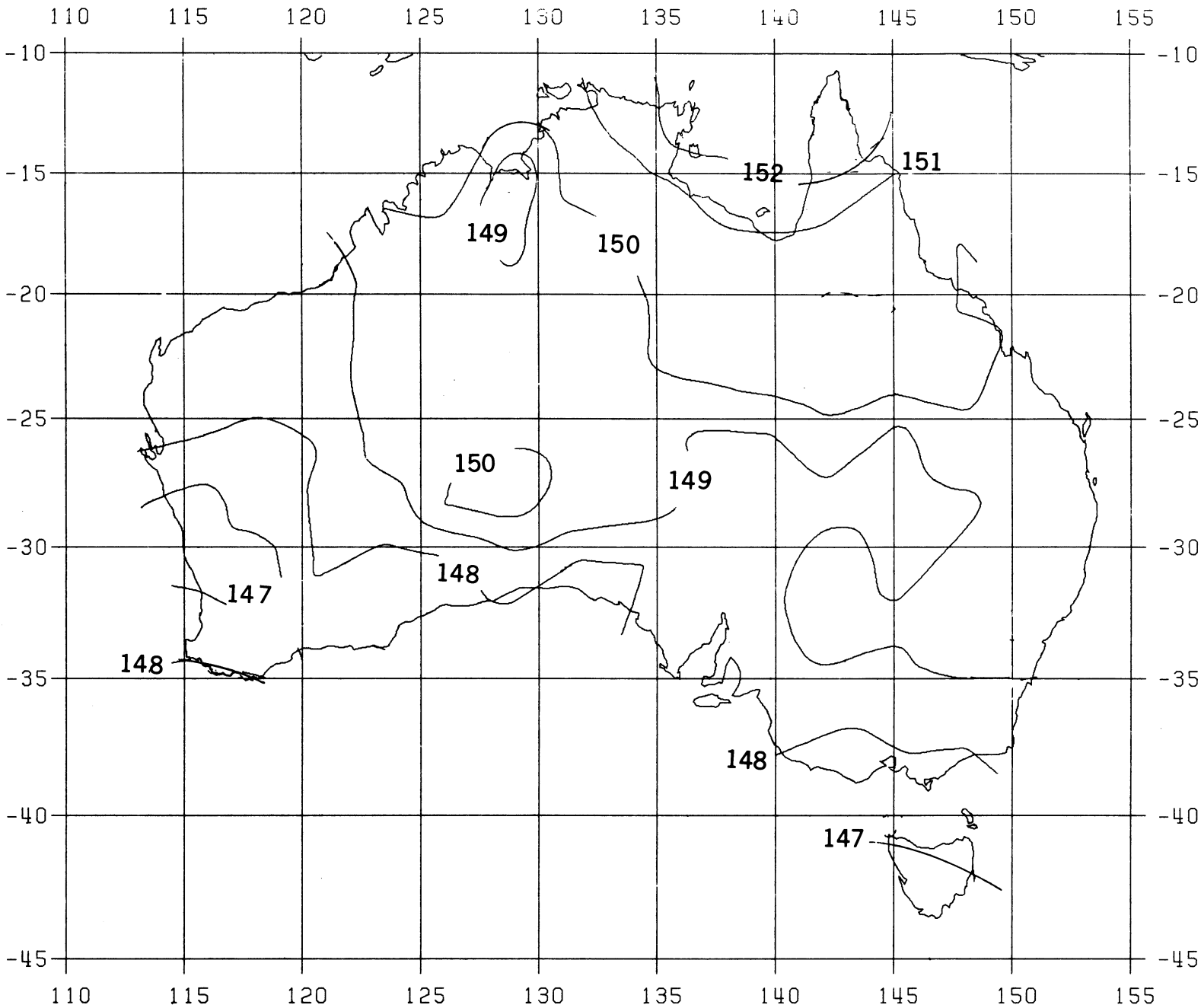

Figure 13.27. Contour Chart – AGD 84 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

SECTION 14

[Revised: 30 September 1988]

LOCAL GEODETIC SYSTEM-TO-WGS 84 DATUM SHIFTS

- ΔX, ΔY, ΔZ CONTOUR CHARTS FOR AN ADDITIONAL 29 OF THE 83 LOCAL GEODETIC SYSTEMS* -

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* CONTOUR CHARTS NOT INCLUDED FOR EUROPEAN DATUM 1979 (SINCE IT DOES NOT REPLACE ED 50), OR FOR THOSE LOCAL GEODETIC SYSTEMS WHERE THE USE OF DATUM SHIFT CONTOUR CHARTS WOULD HAVE LITTLE OR NO PRACTICAL VALUE (MOST ISLAND DATUMS AND/OR DATUMS WITH ONLY A VERY SMALL NUMBER OF DOPPLER DATUM TRANSFORMATION STATIONS, AND/OR DATUMS REPRESENTING SMALL GEOGRAPHICAL AREAS). FOR ΔX, ΔY, ΔZ VALUES FOR SUCH LOCAL GEODETIC SYSTEMS, SEE TABLE 10.1. THE FOOTNOTE TO PAGE 13-1 ALSO APPLIES HERE.

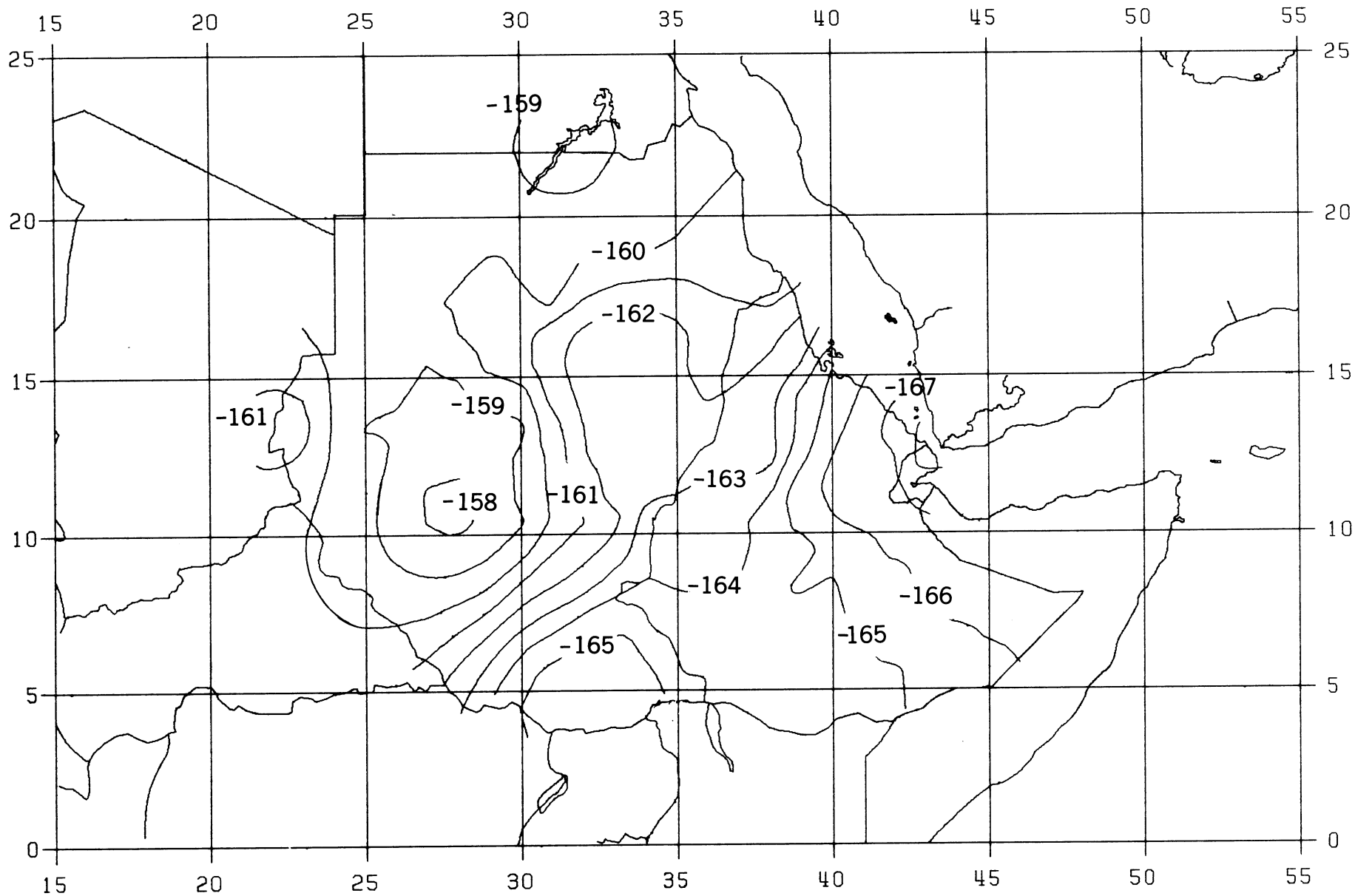

Figure 14.1. Contour Chart - Adindan Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

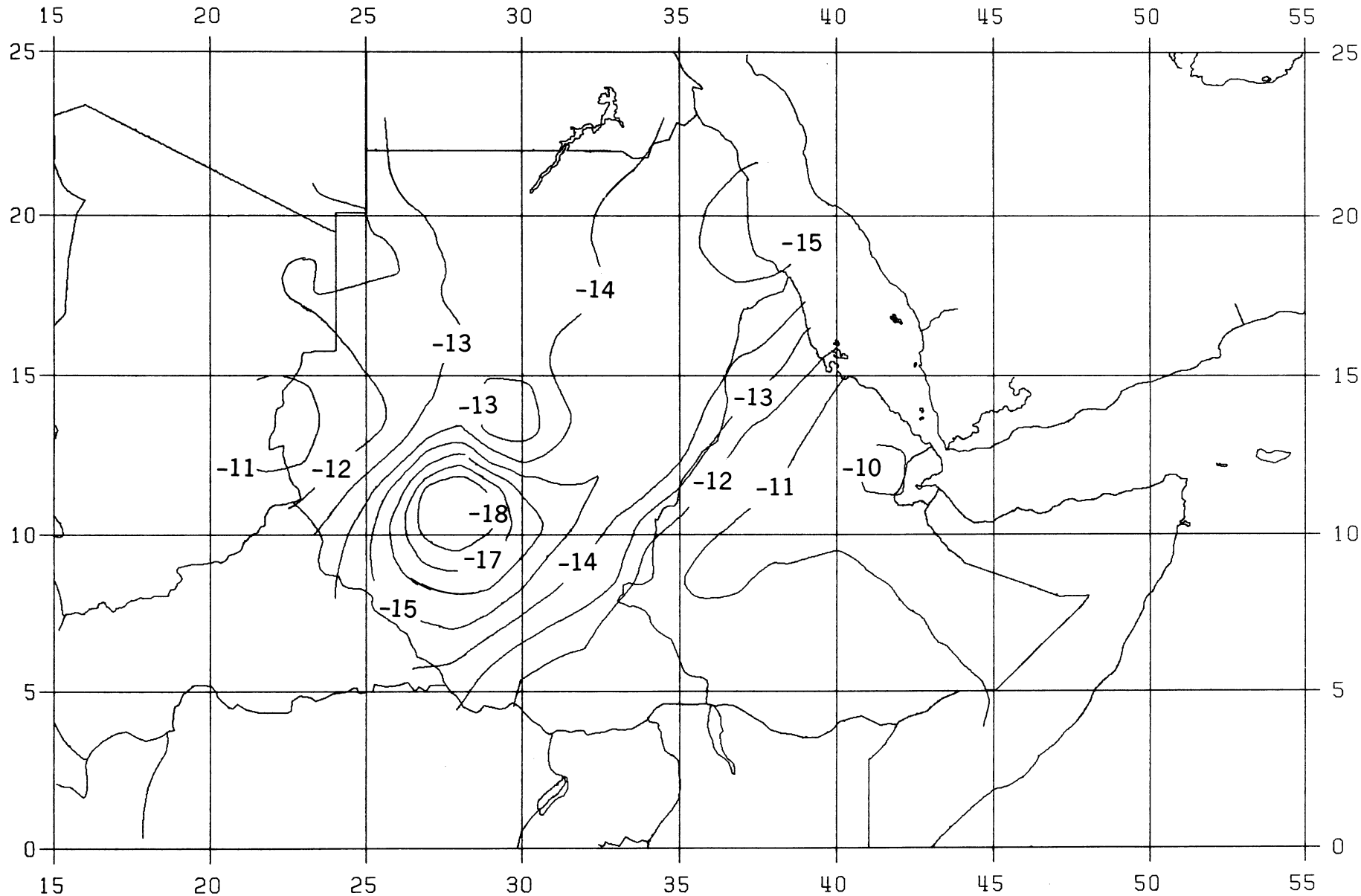

Figure 14.2. Contour Chart - Adindan Datum to WGS 84 Datum Shifts, △Y Component (Contour Interval = 1 Meter)

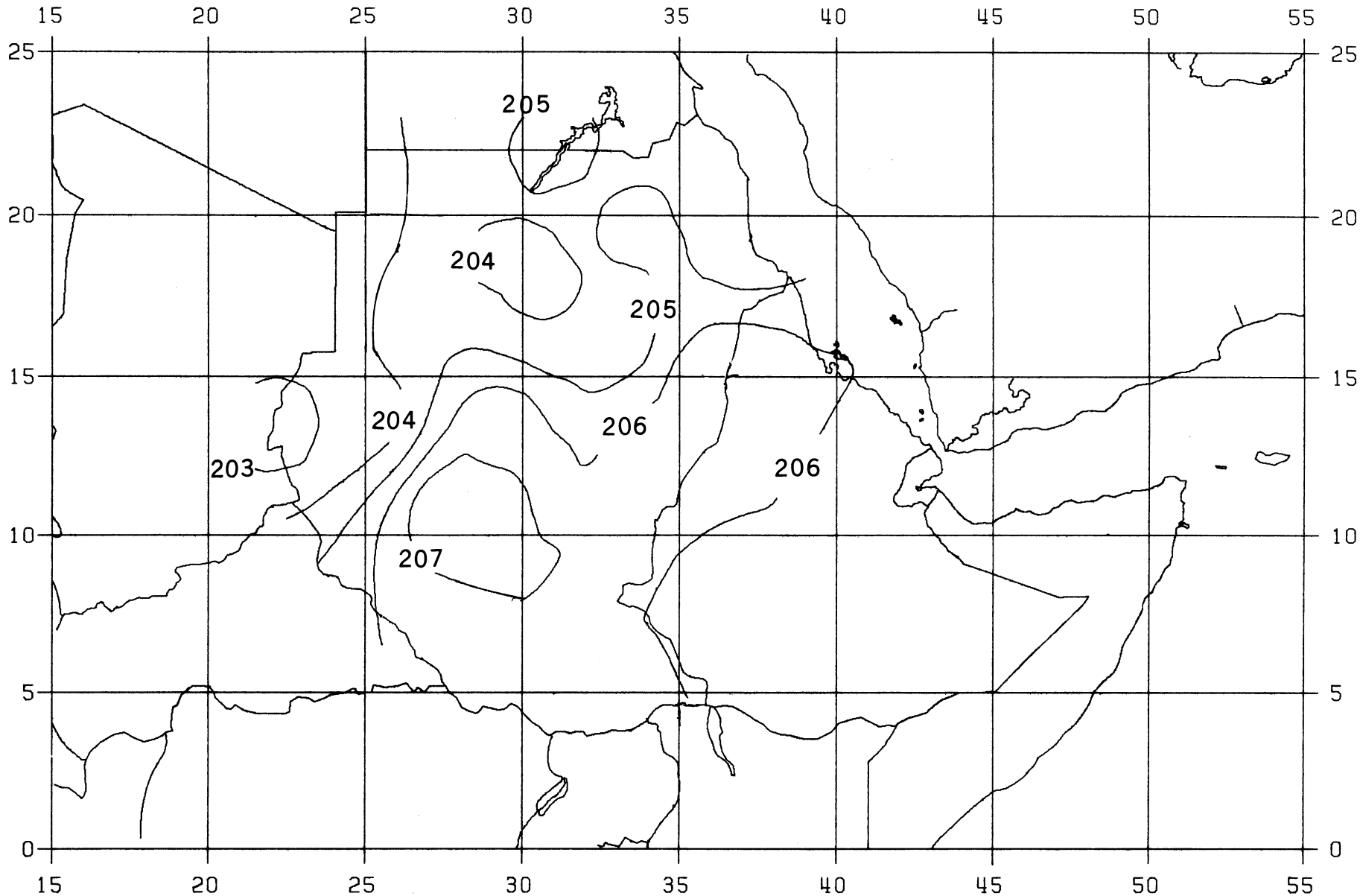

Figure 14.3. Contour Chart – Adindan Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

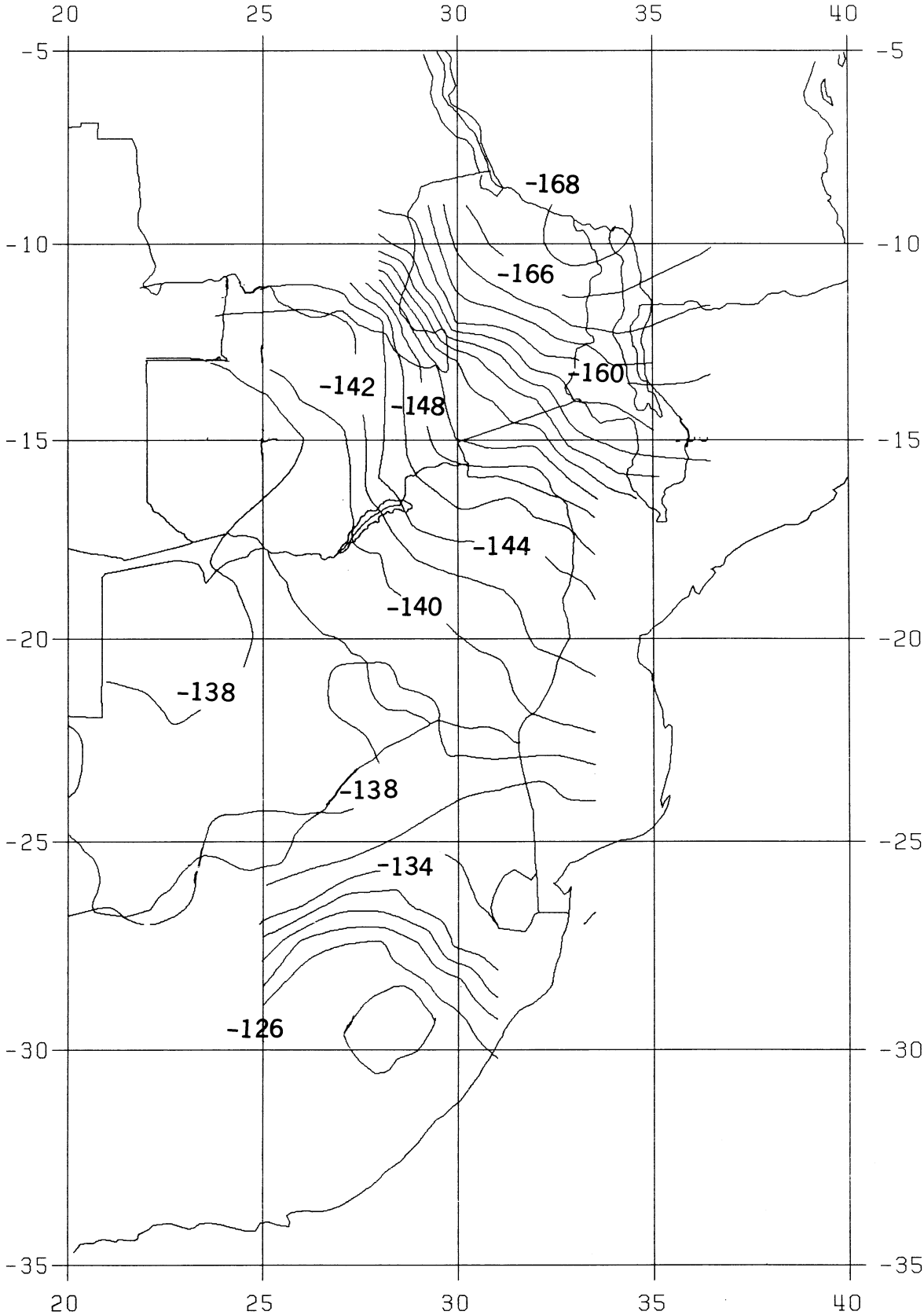

Figure 14.4. Contour Chart - Arc Datum 1950 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 2 Meters)

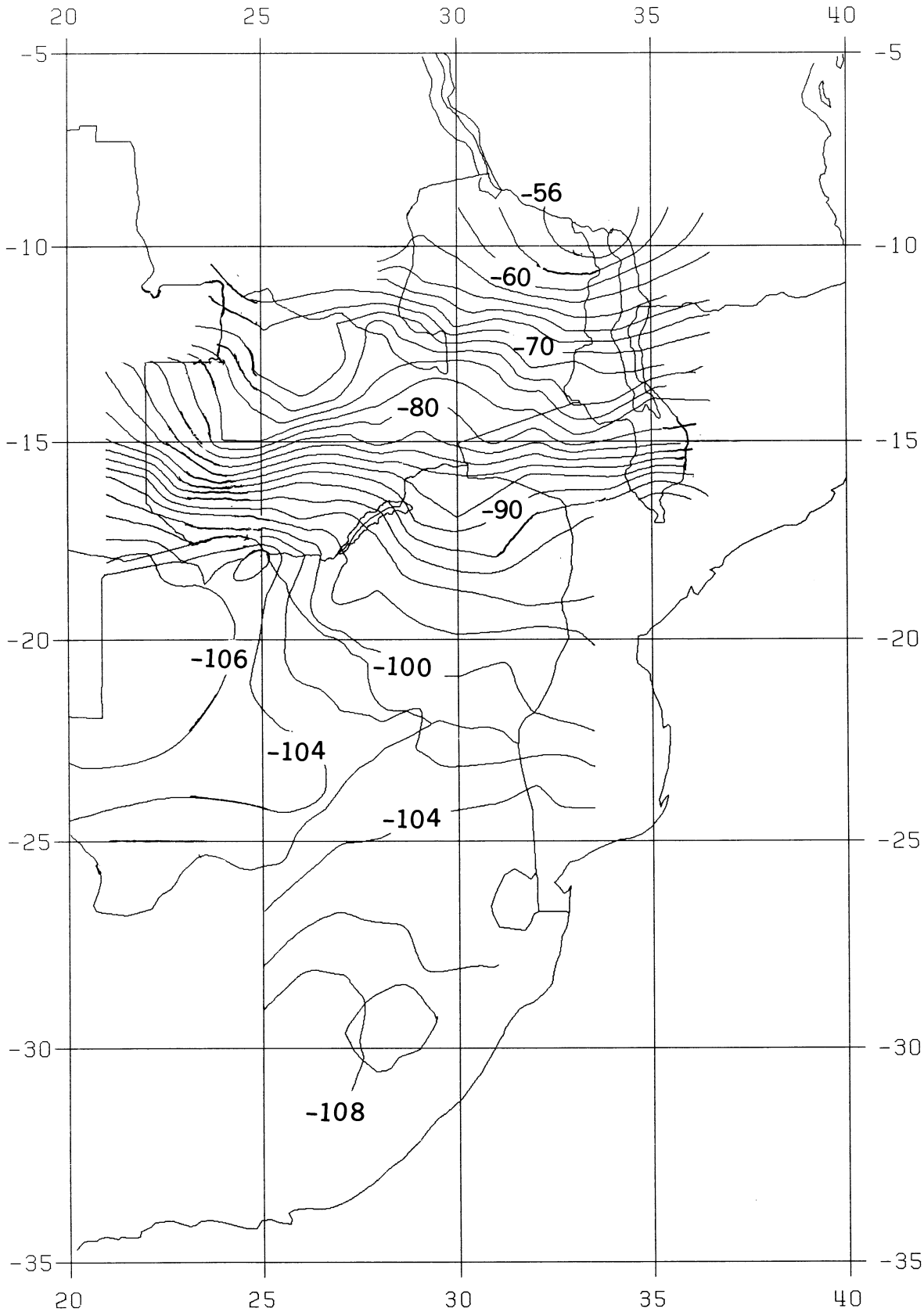

Figure 14.5. Contour Chart – Arc Datum 1950 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 2 Meters)

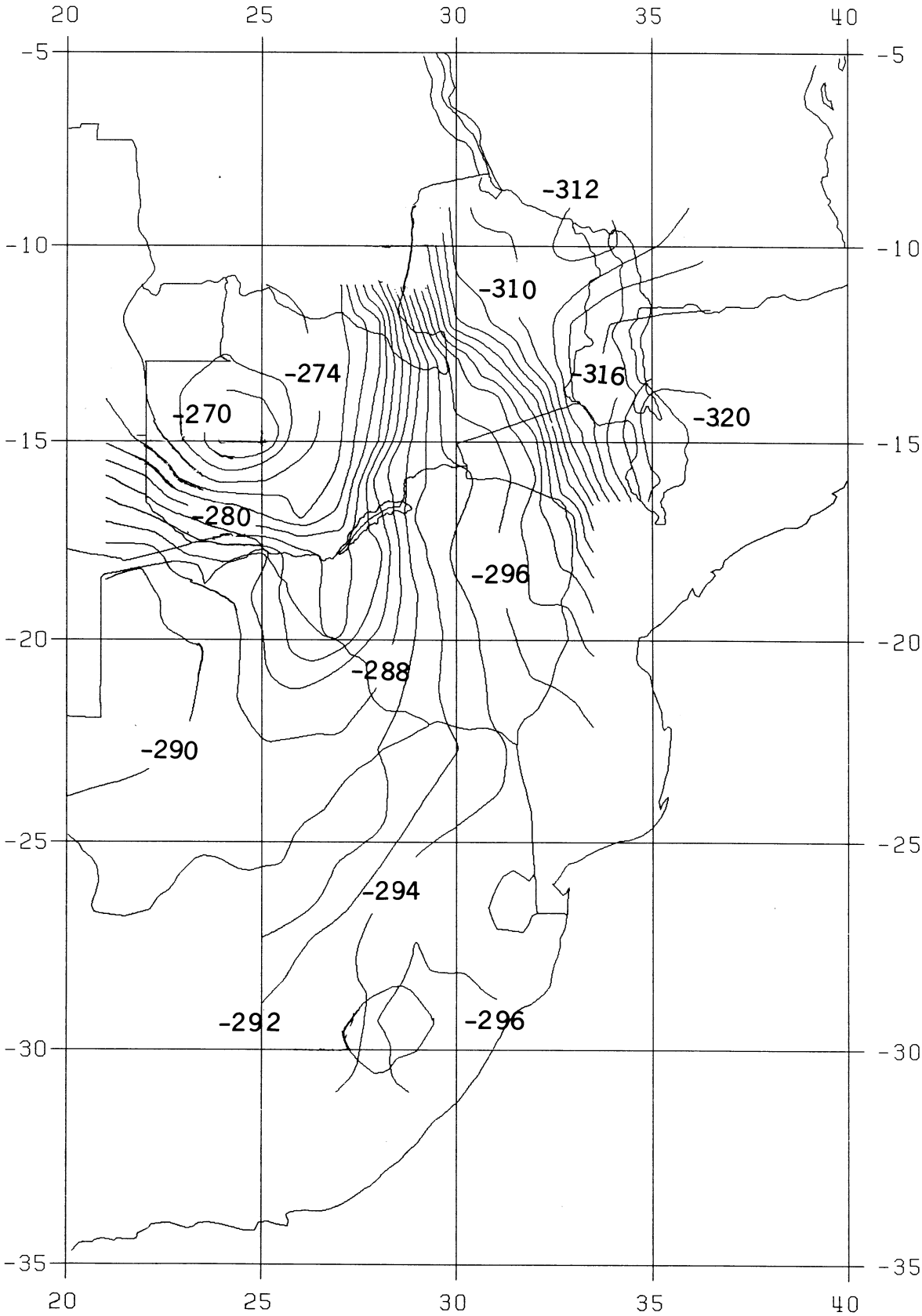

Figure 14.6. Contour Chart - Arc Datum 1950 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 2 Meters)

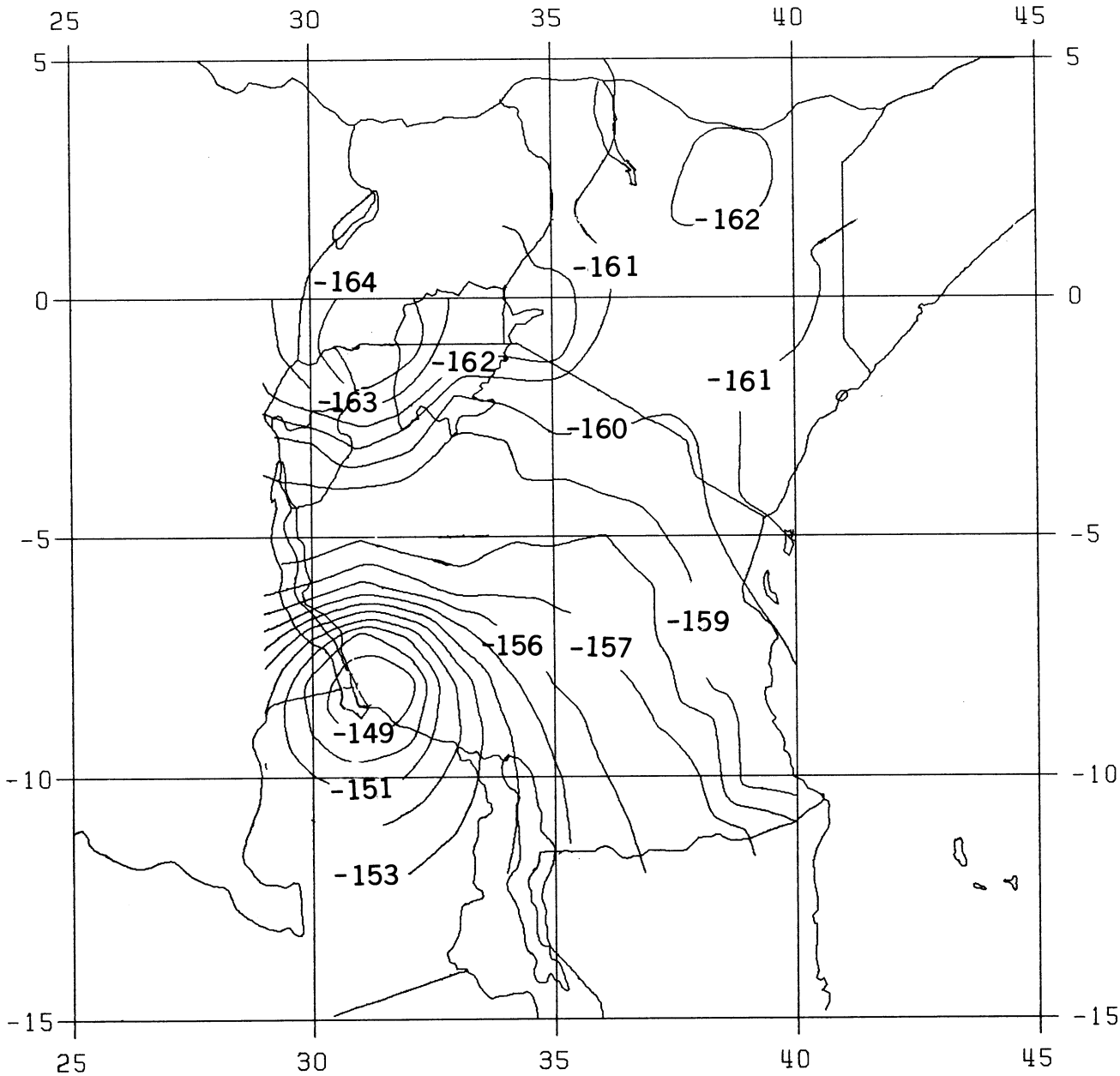

Figure 14.7. Contour Chart - Arc Datum 1960 to WGS 84 Datum Shifts, △X Component (Contour Interval = 1 Meter)

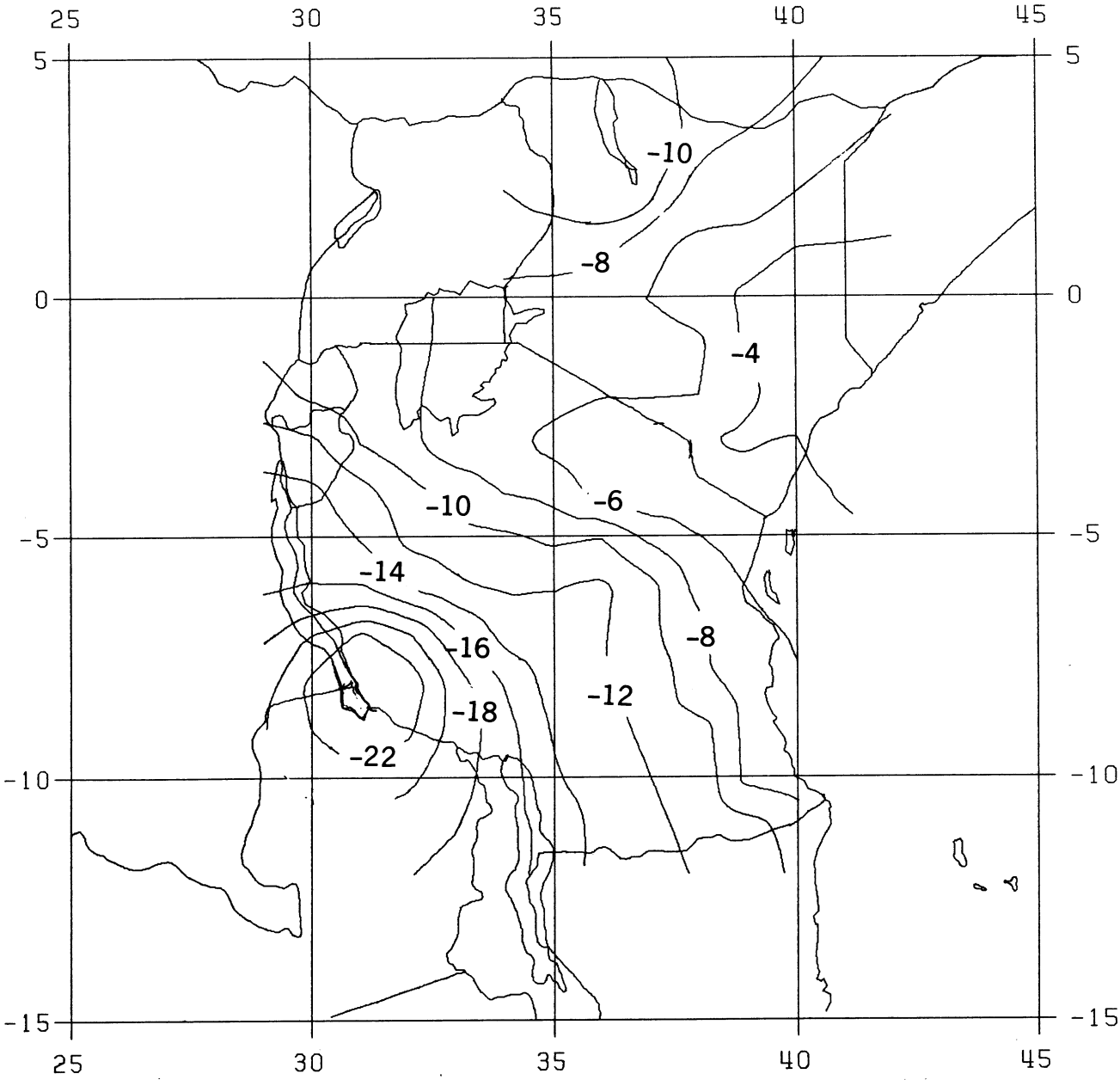

Figure 14.8. Contour Chart – Arc Datum 1960 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 2 Meters)

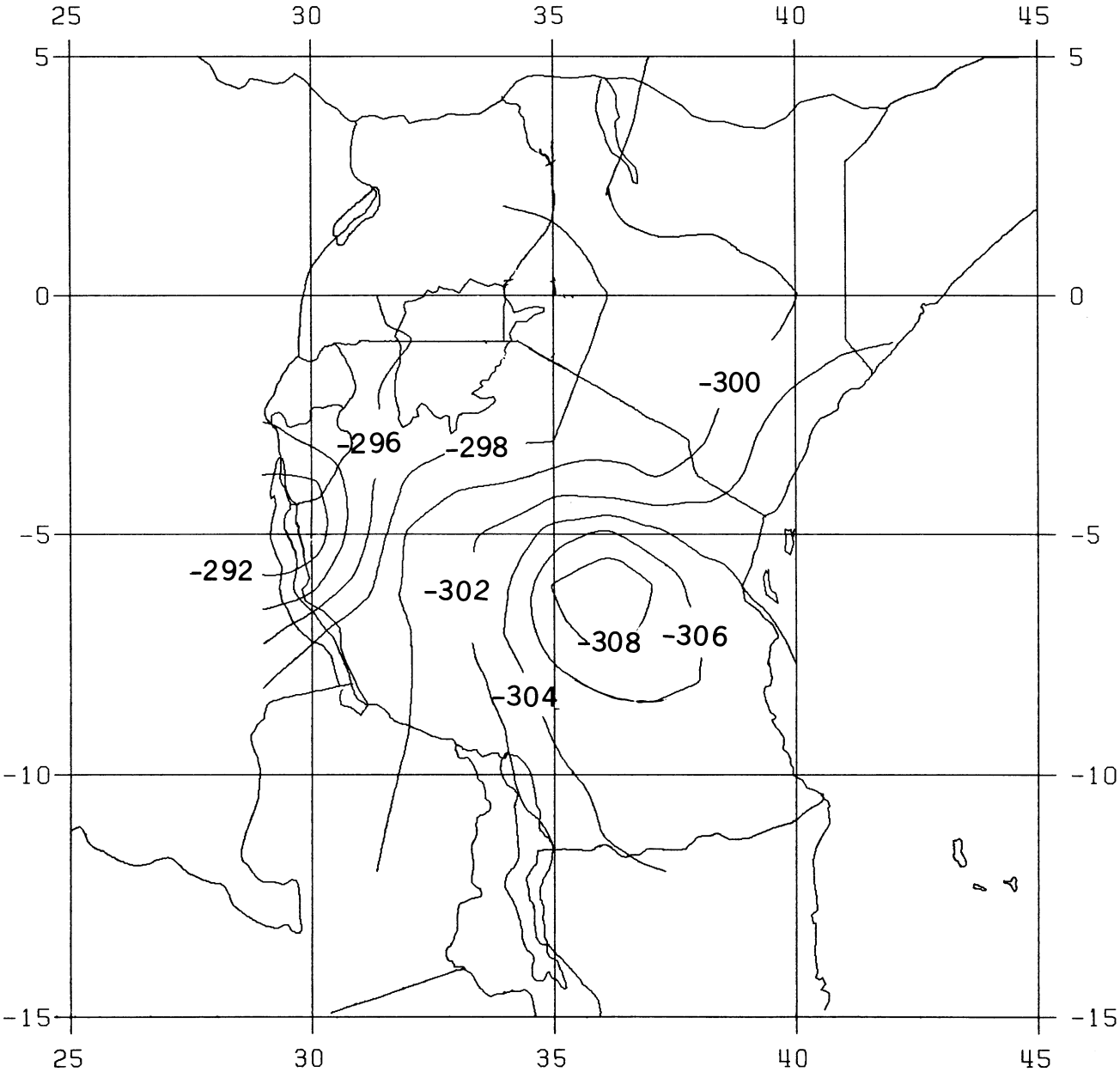

Figure 14.9. Contour Chart – Arc Datum 1960 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 2 Meters)

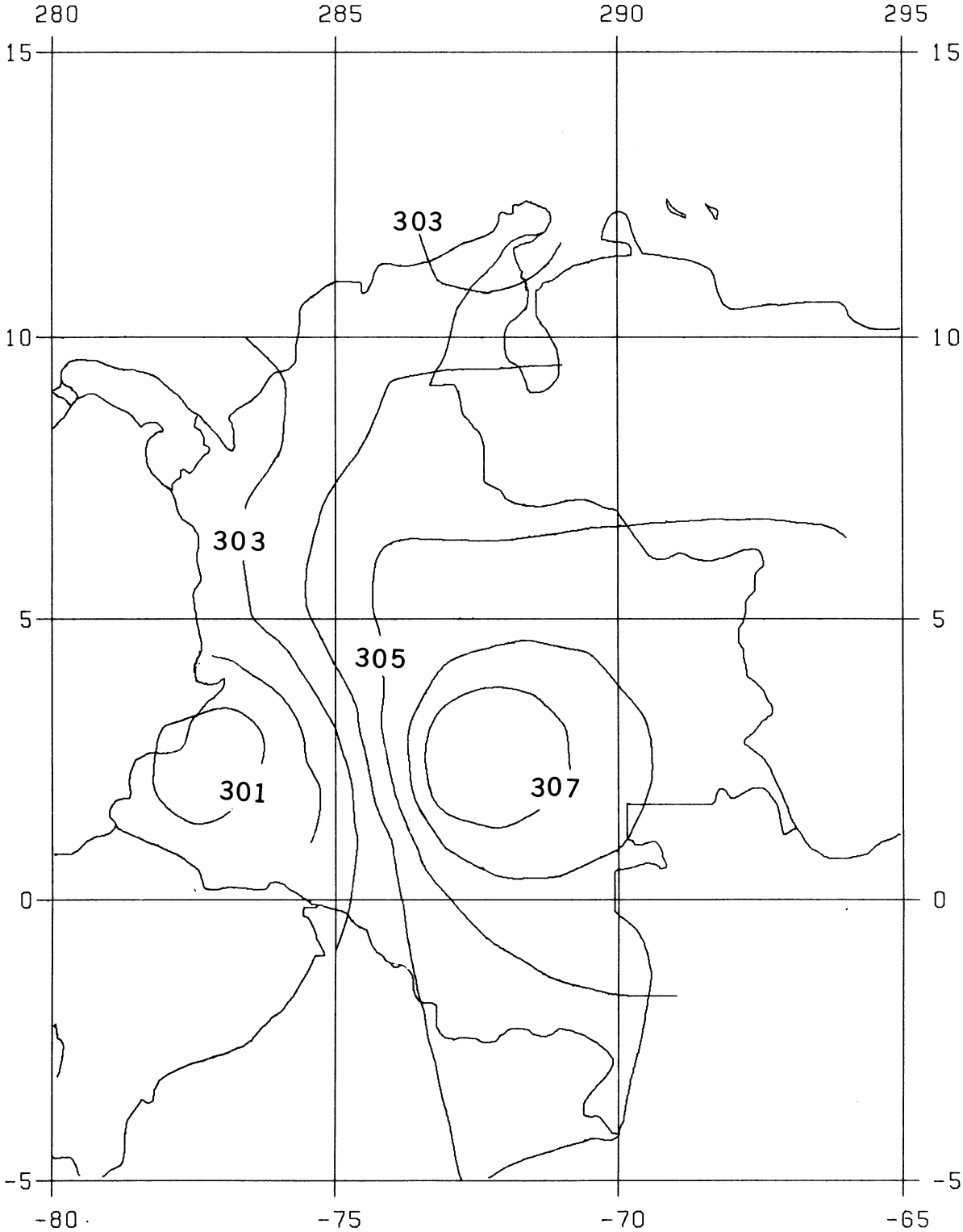

Figure 14.10. Contour Chart - Bogota Observatory Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

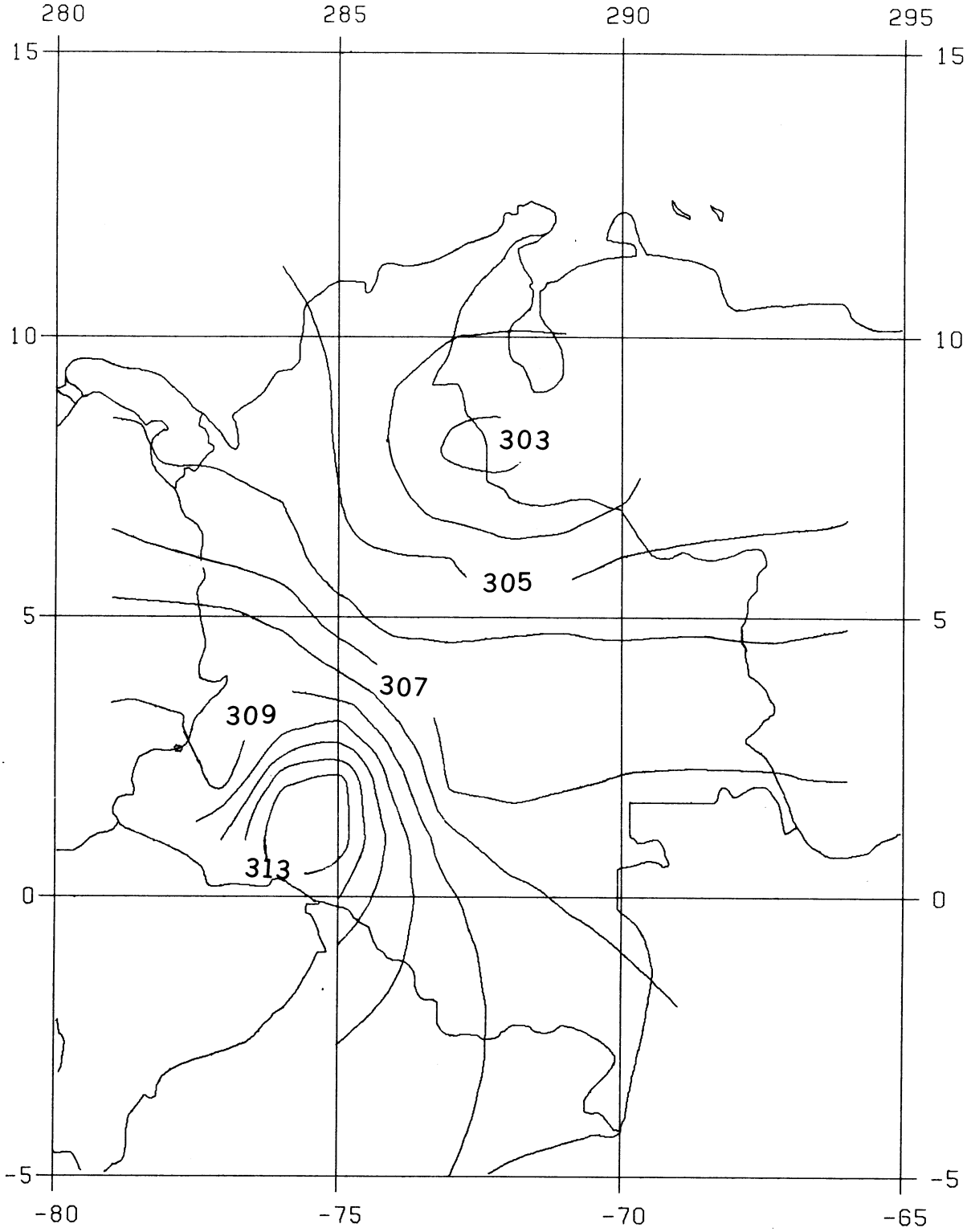

Figure 14.11. Contour Chart - Bogota Observatory Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

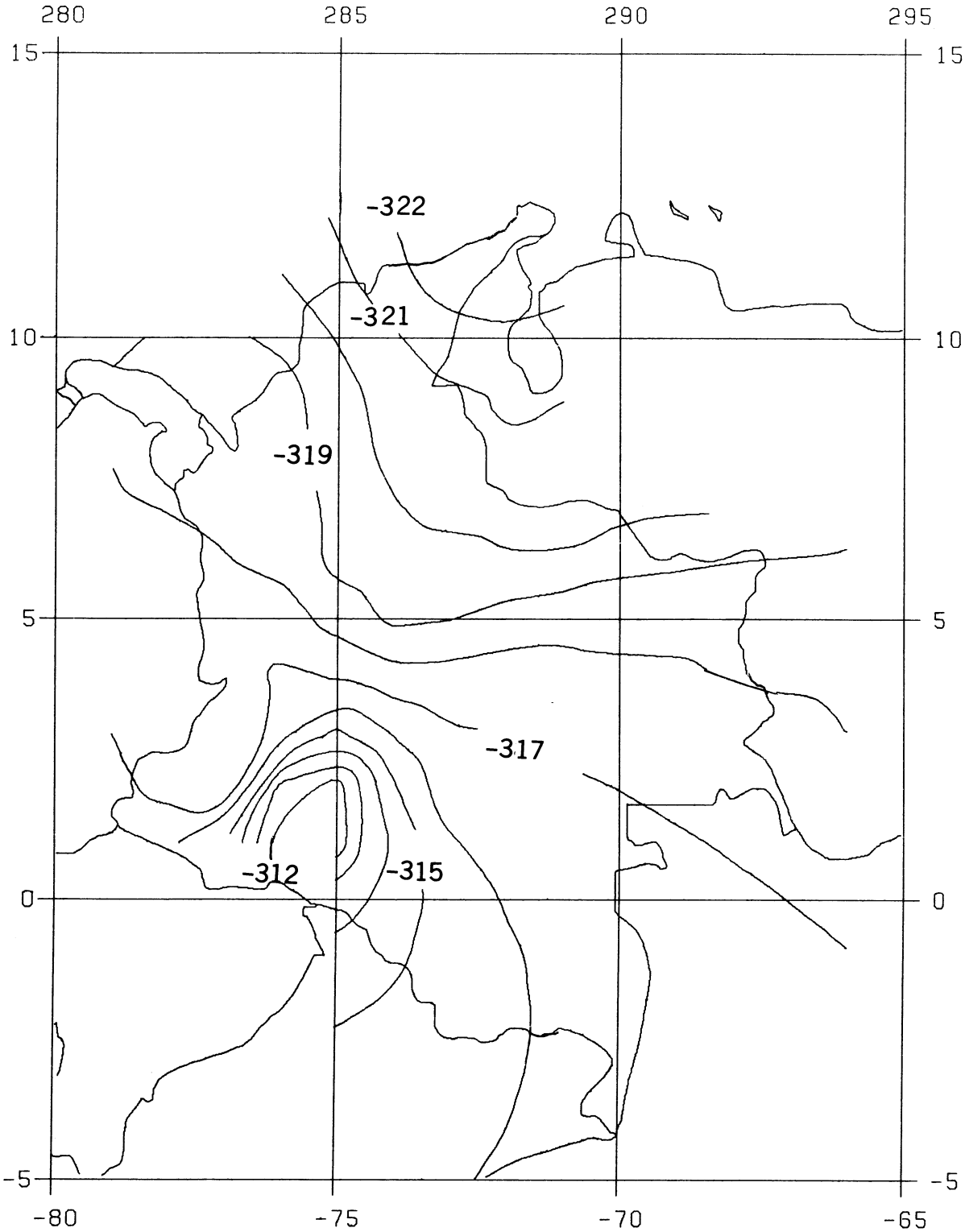

Figure 14.12. Contour Chart - Bogota Observatory Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

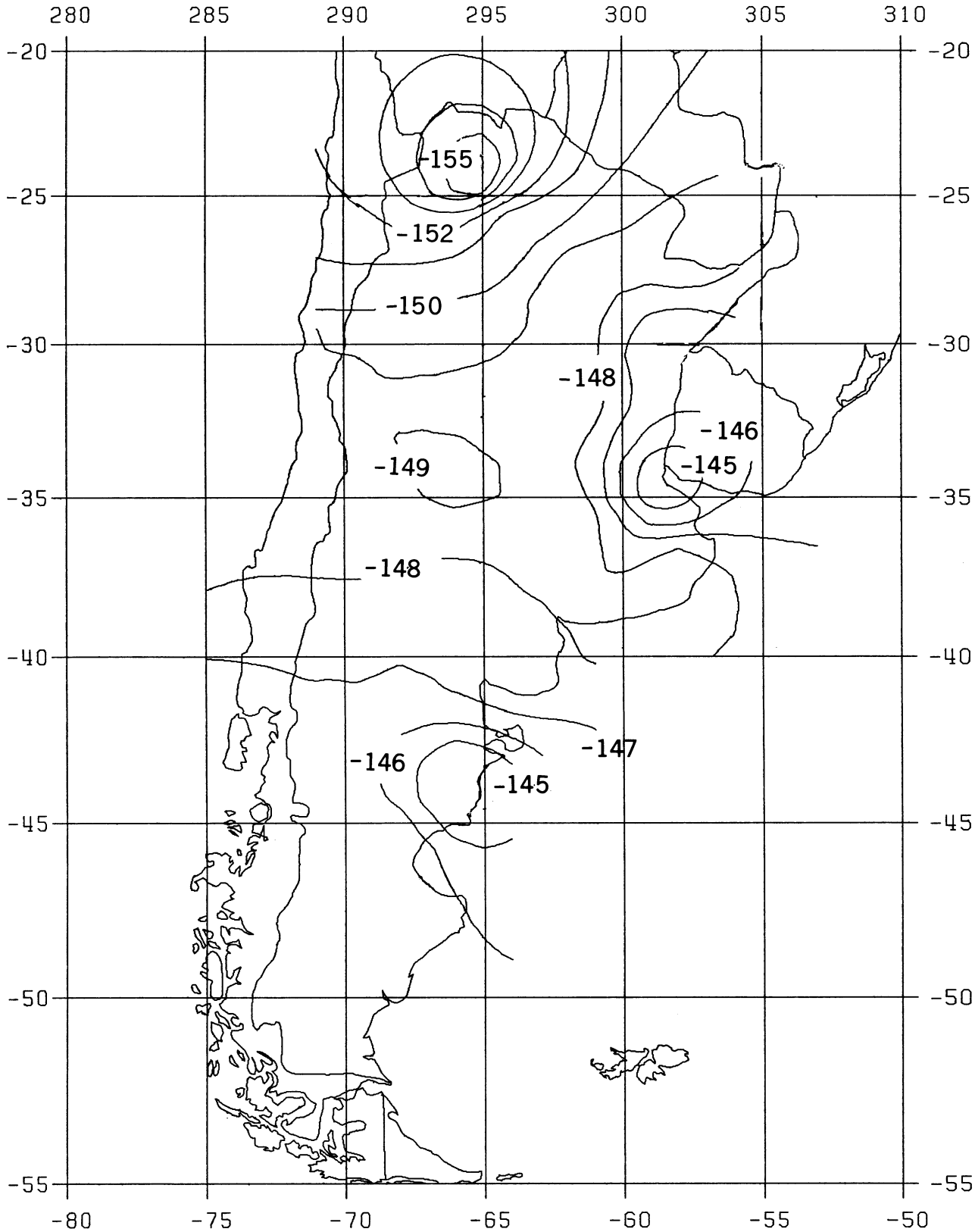

Figure 14.13. Contour Chart – Campo Inchauspe Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

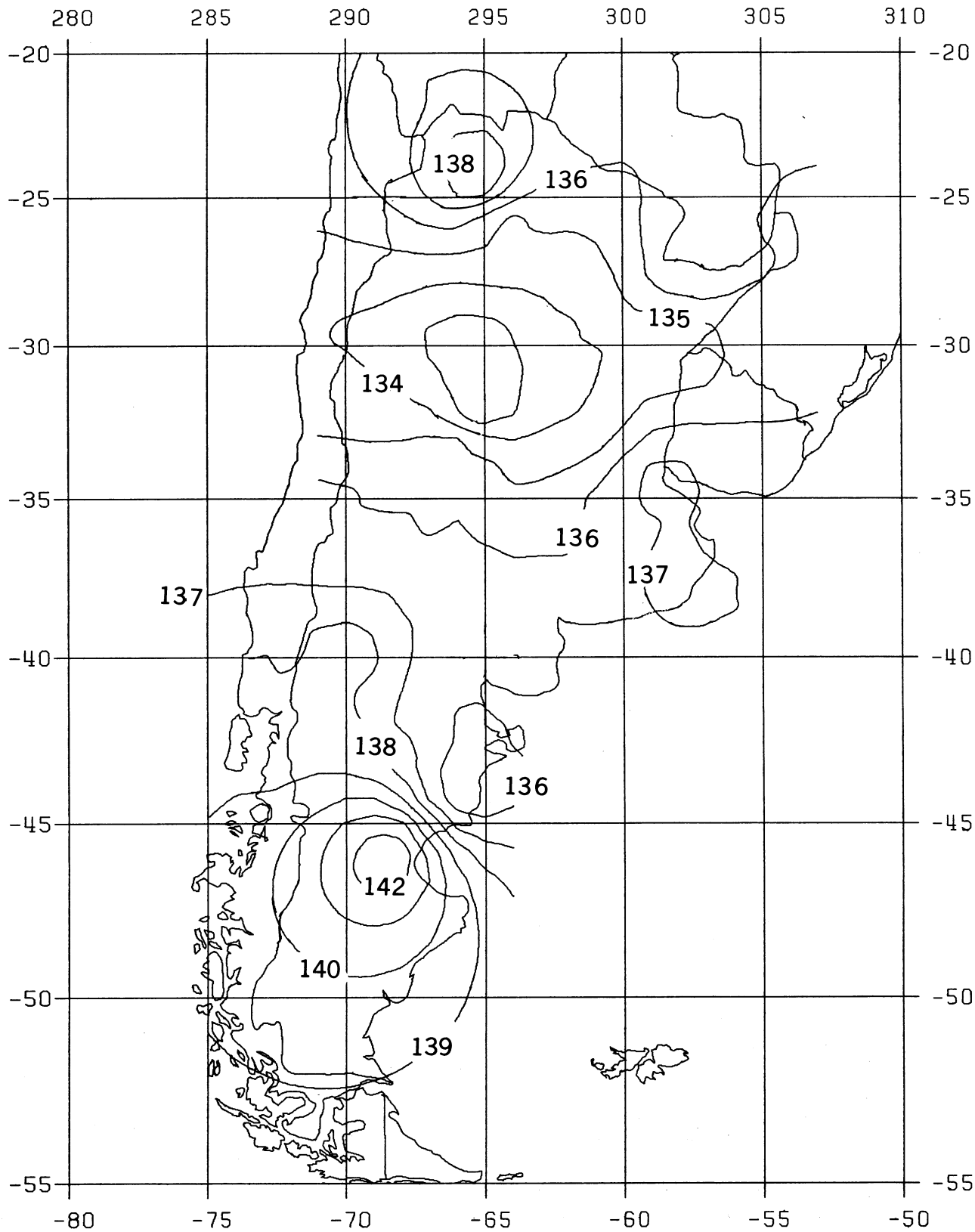

Figure 14.14. Contour Chart - Campo Inchauspe Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

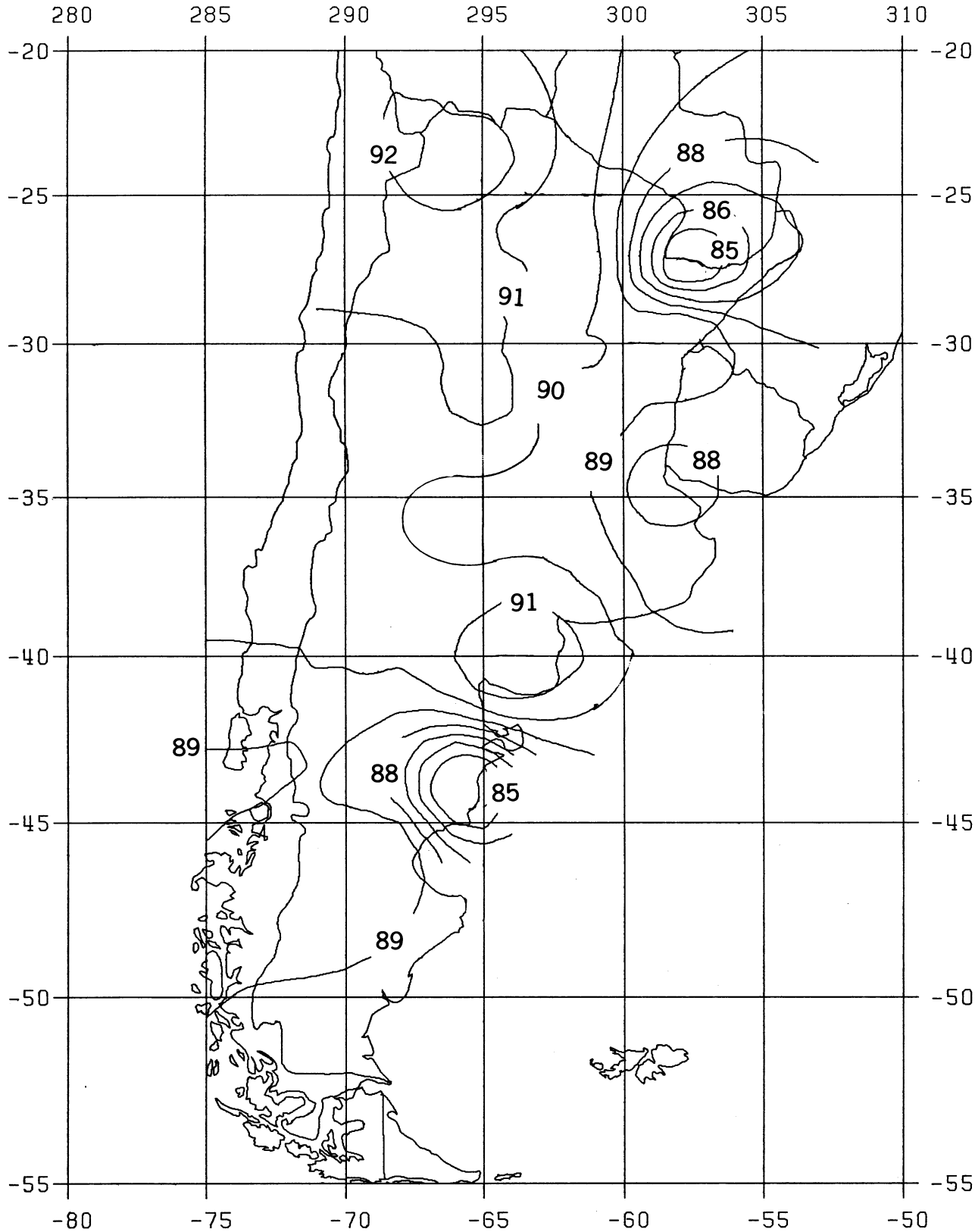

Figure 14.15. Contour Chart - Campo Inchauspe Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

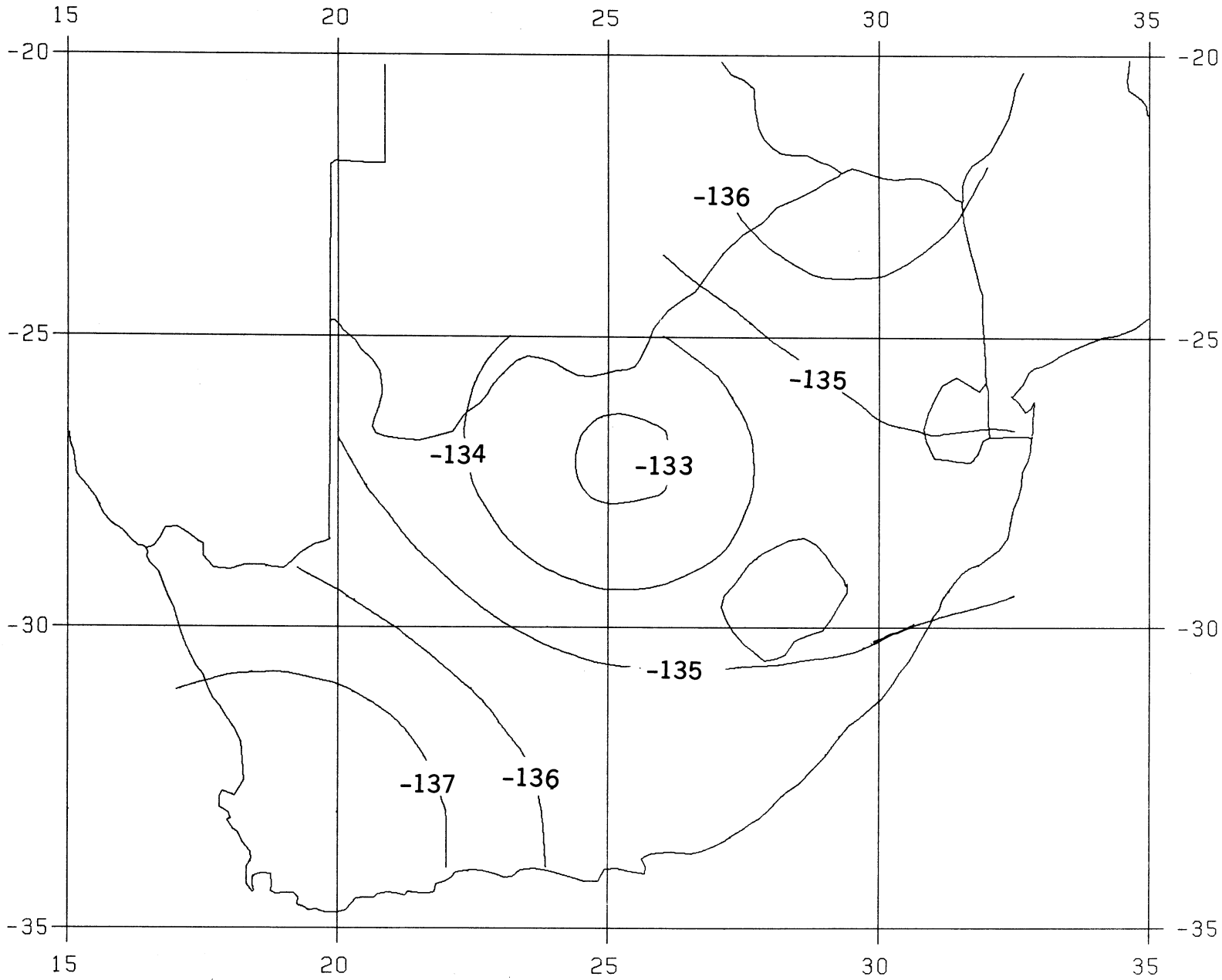

Figure 14.16. Contour Chart – Cape Datum to WGS 84 Datum Shifts, △X Component (Contour Interval = 1 Meter)

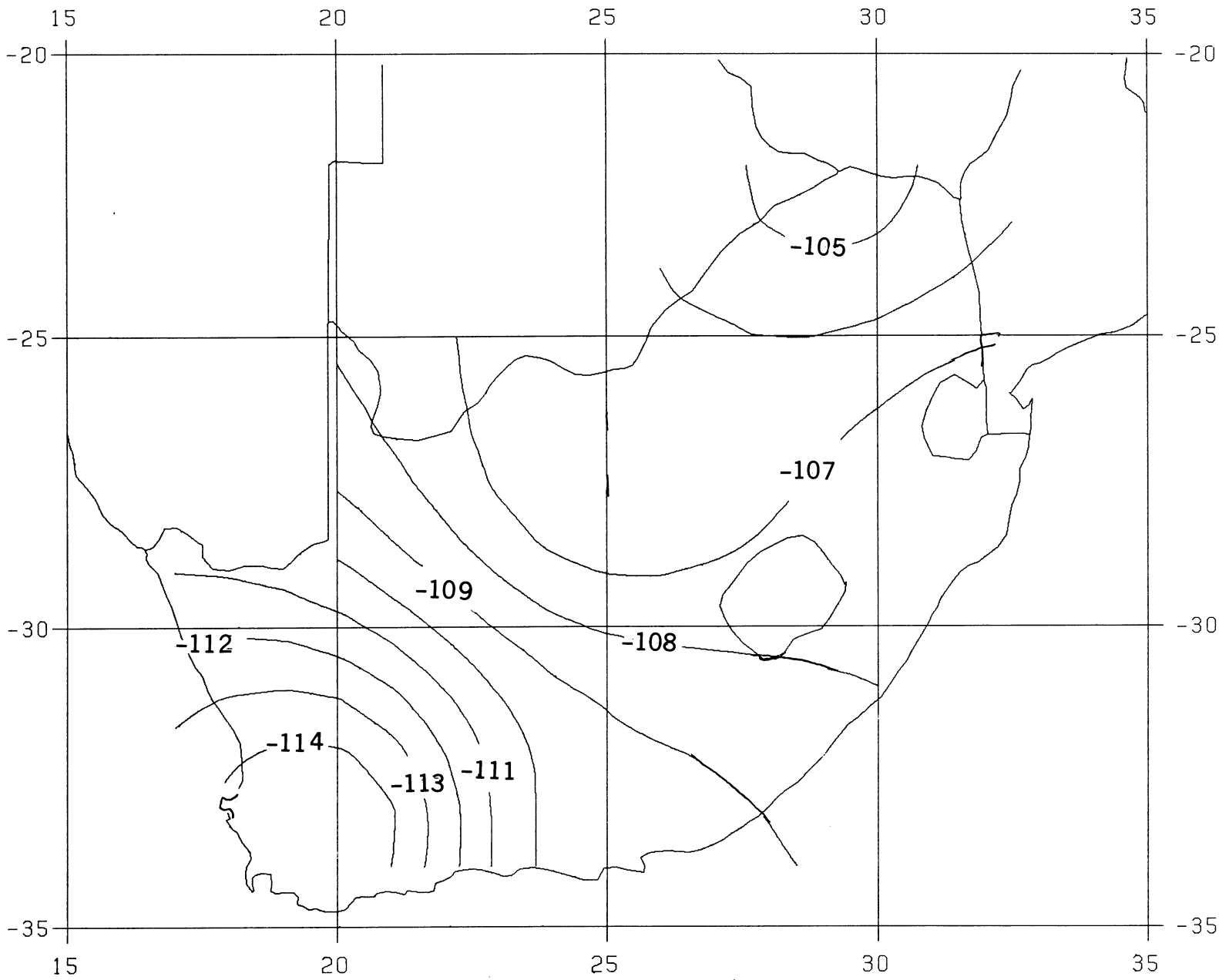

Figure 14.17. Contour Chart - Cape Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

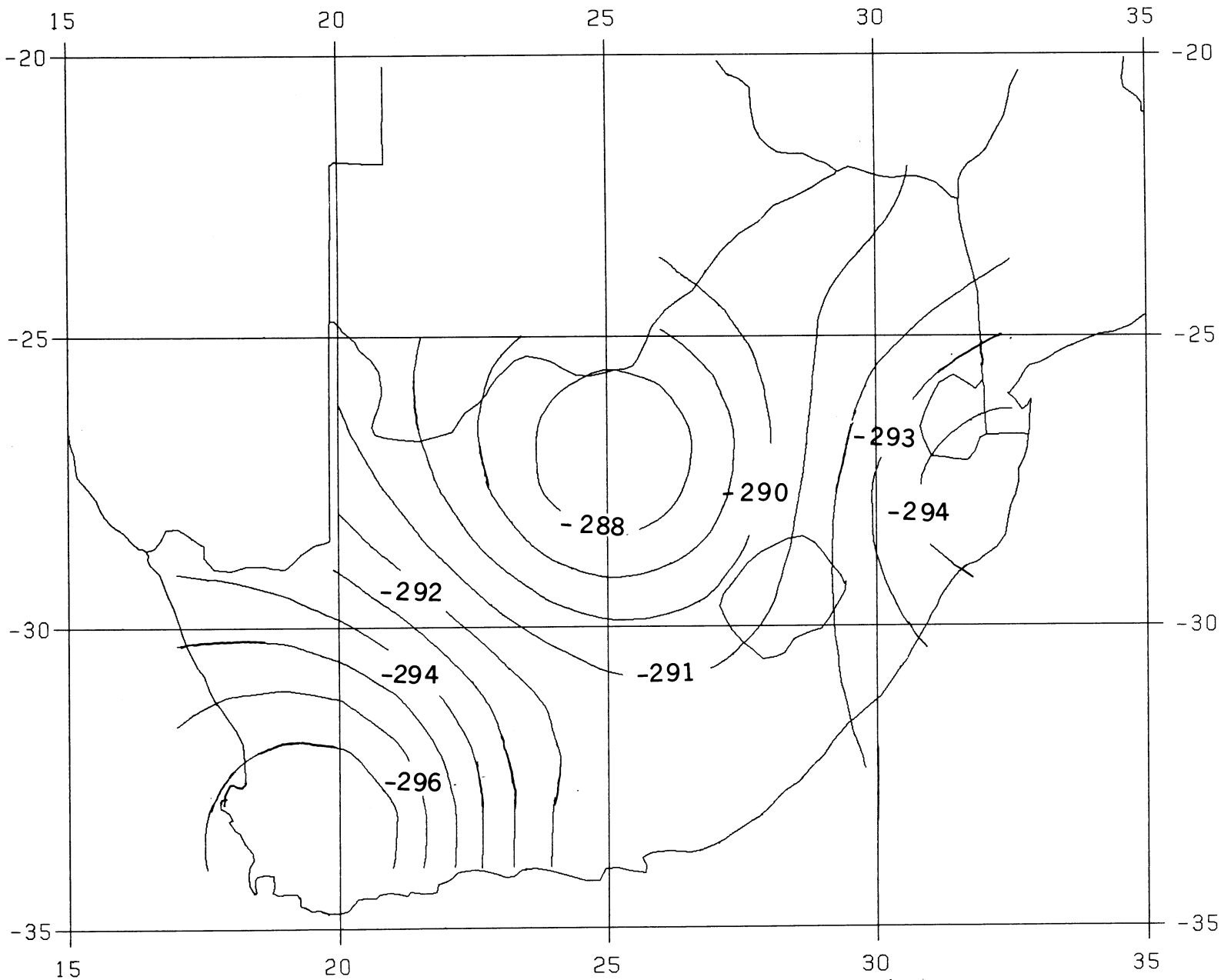

Figure 14.18. Contour Chart – Cape Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

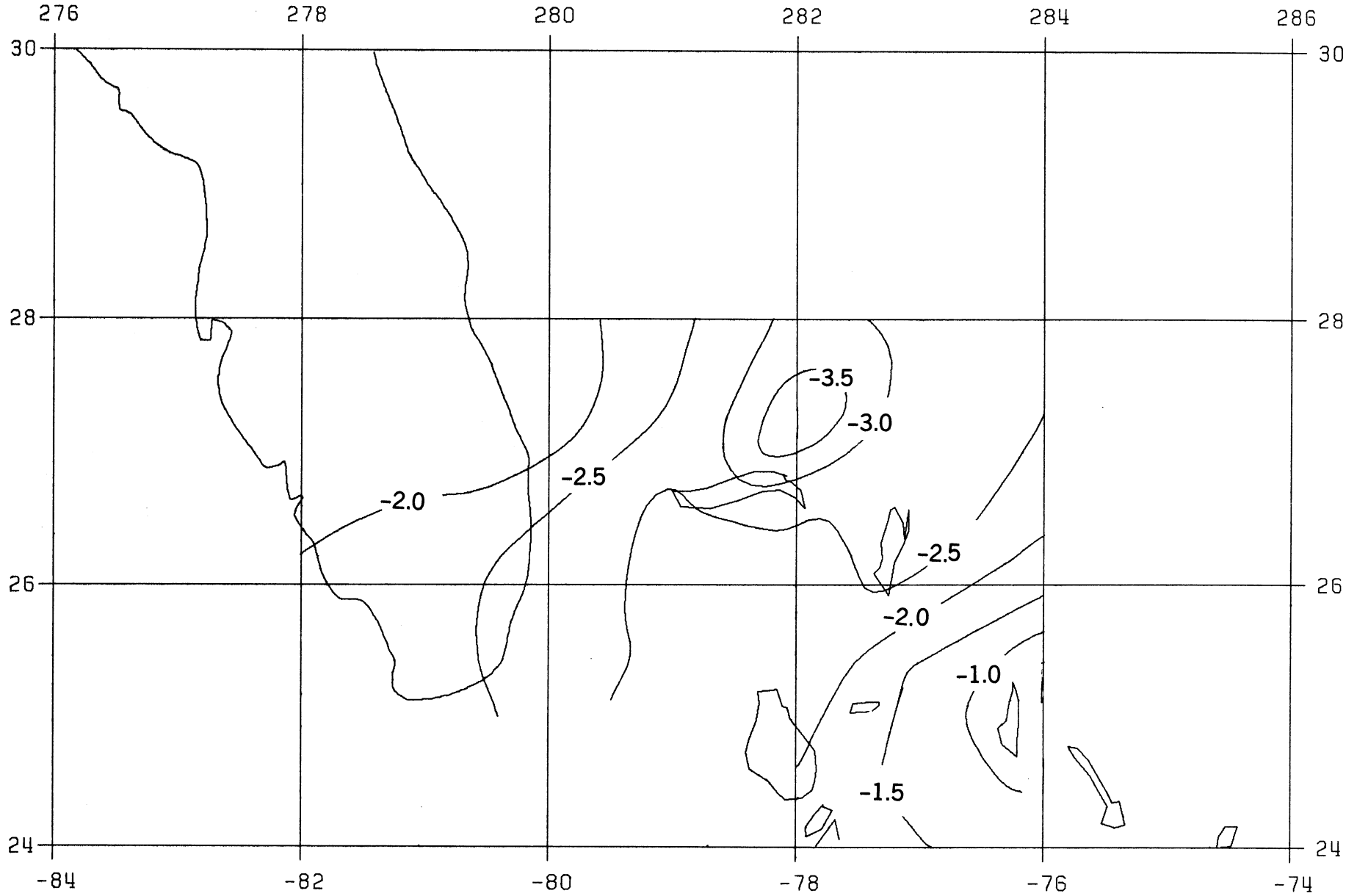

Figure 14.19. Contour Chart - Cape Canaveral Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 0.5 Meter)

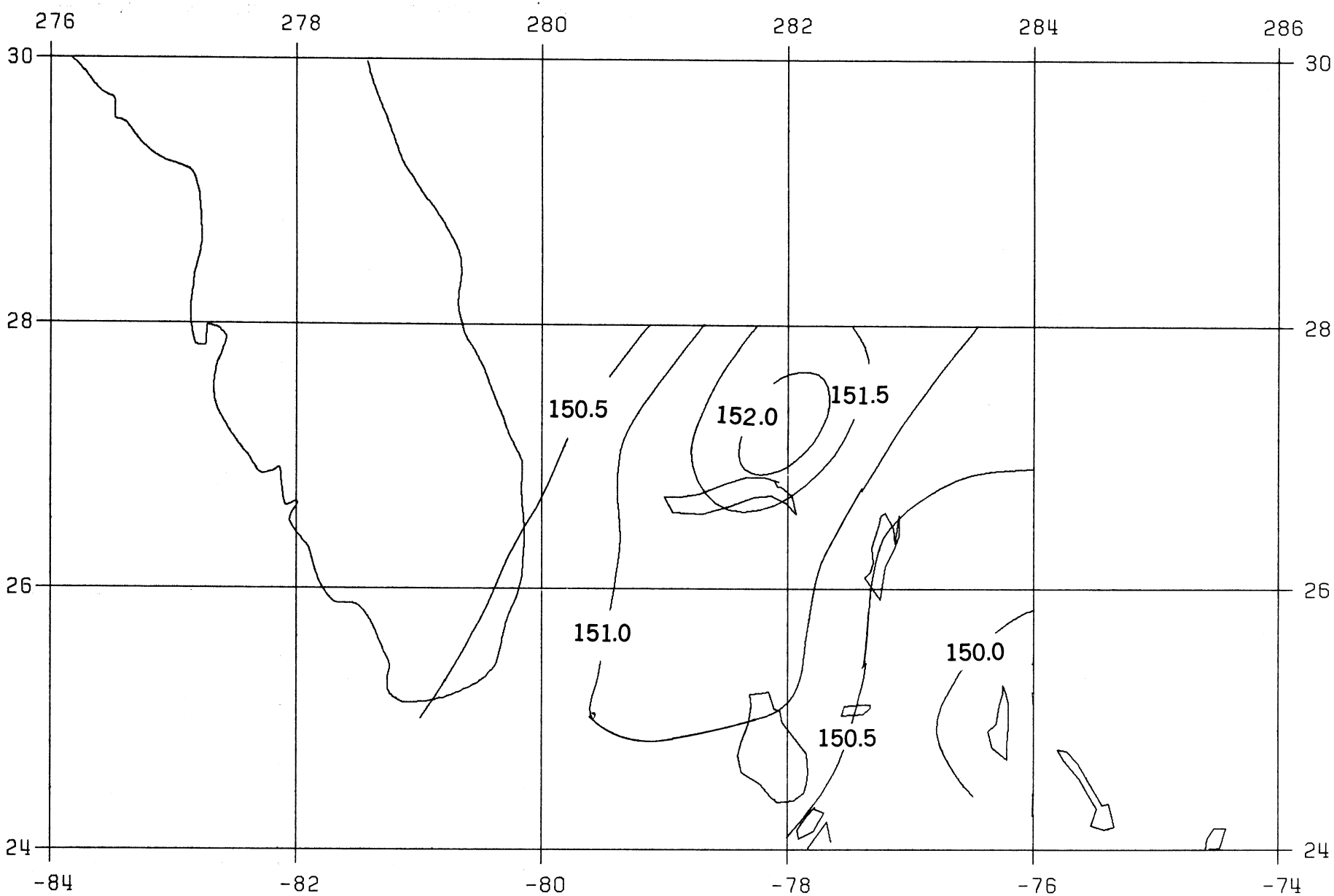

Figure 14.20. Contour Chart - Cape Canaveral Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 0.5 Meter)

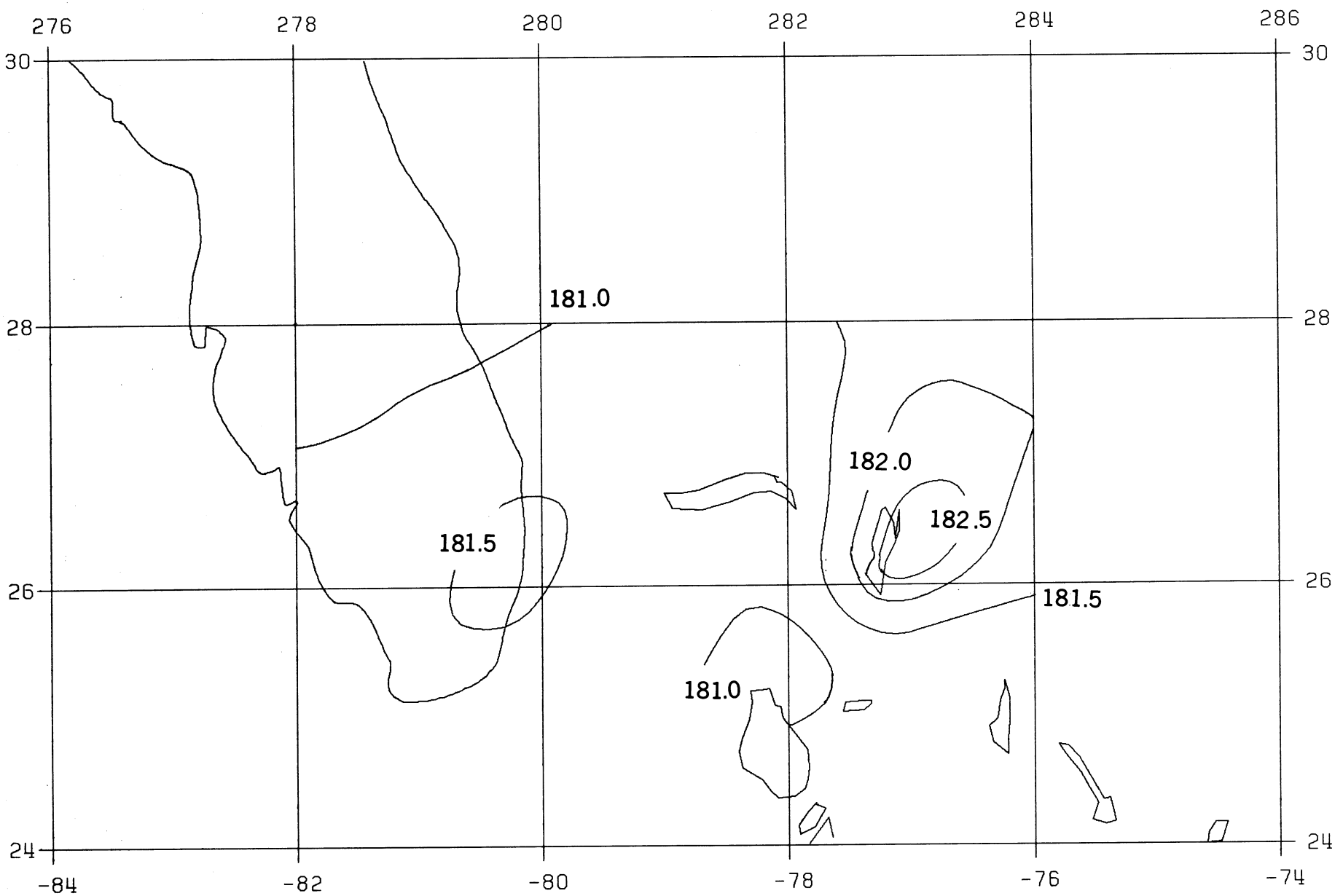

Figure 14.21. Contour Chart – Cape Canaveral Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 0.5 Meter)

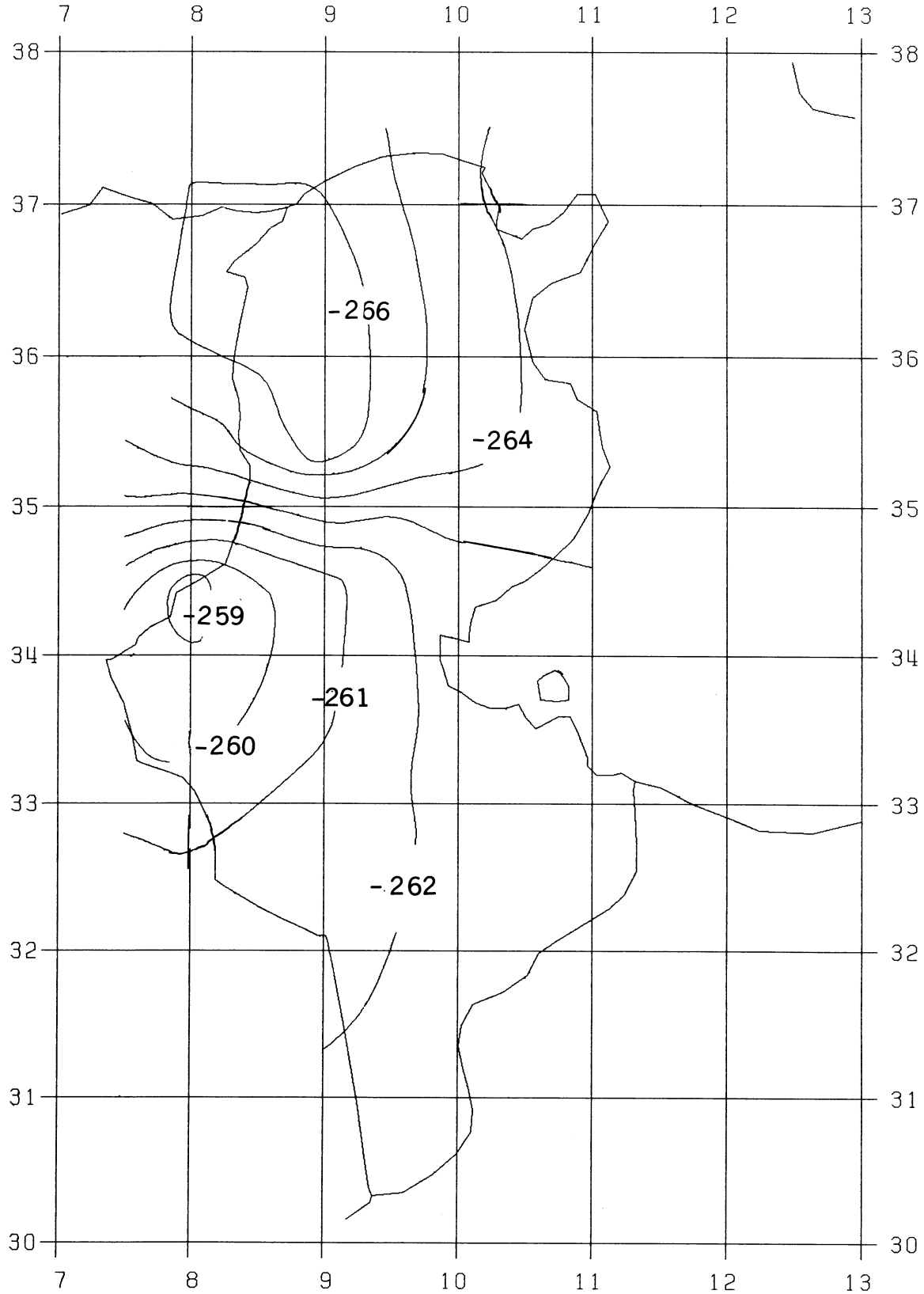

Figure 14.22. Contour Chart – Carthage Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

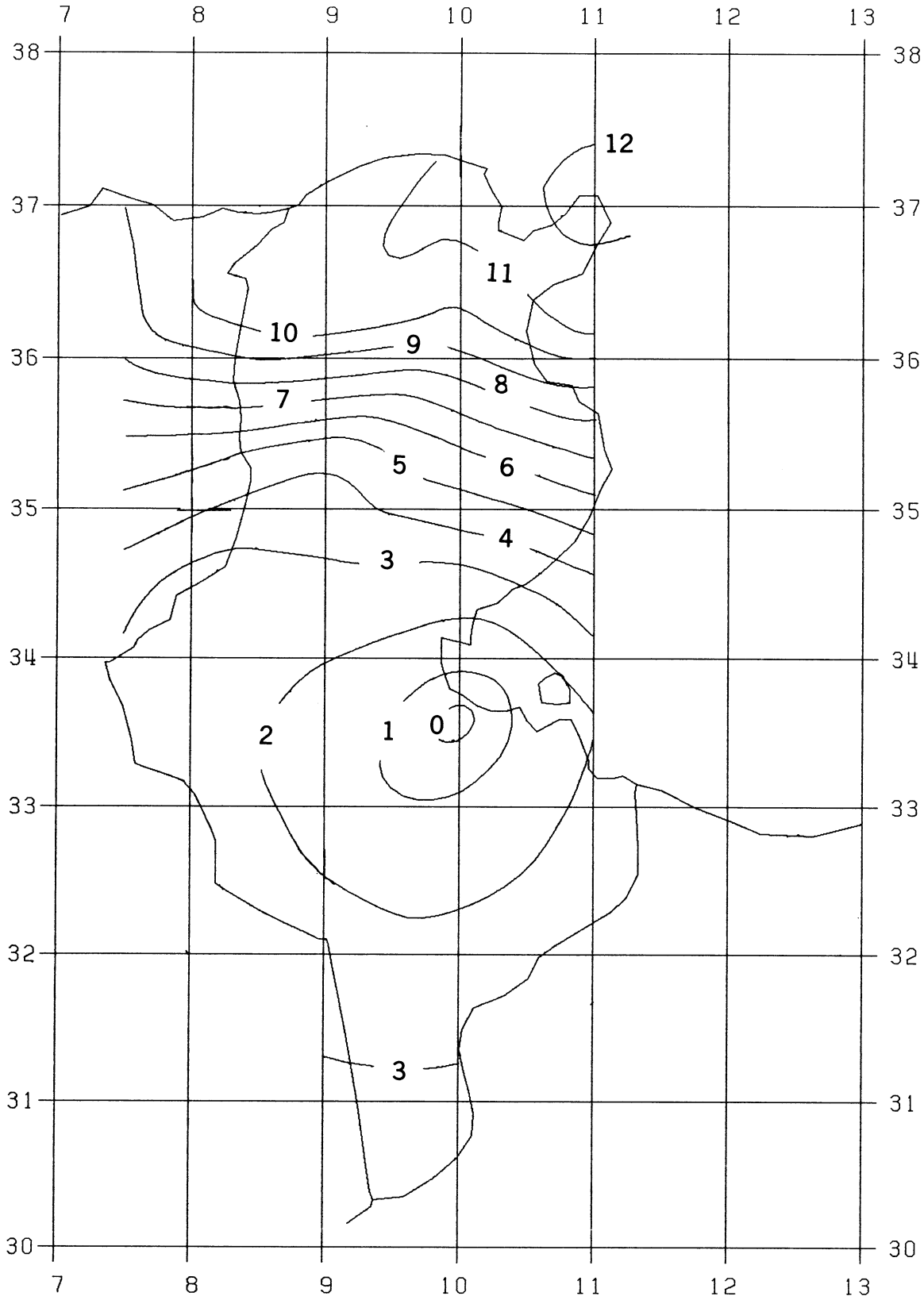

Figure 14.23. Contour Chart – Carthage Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

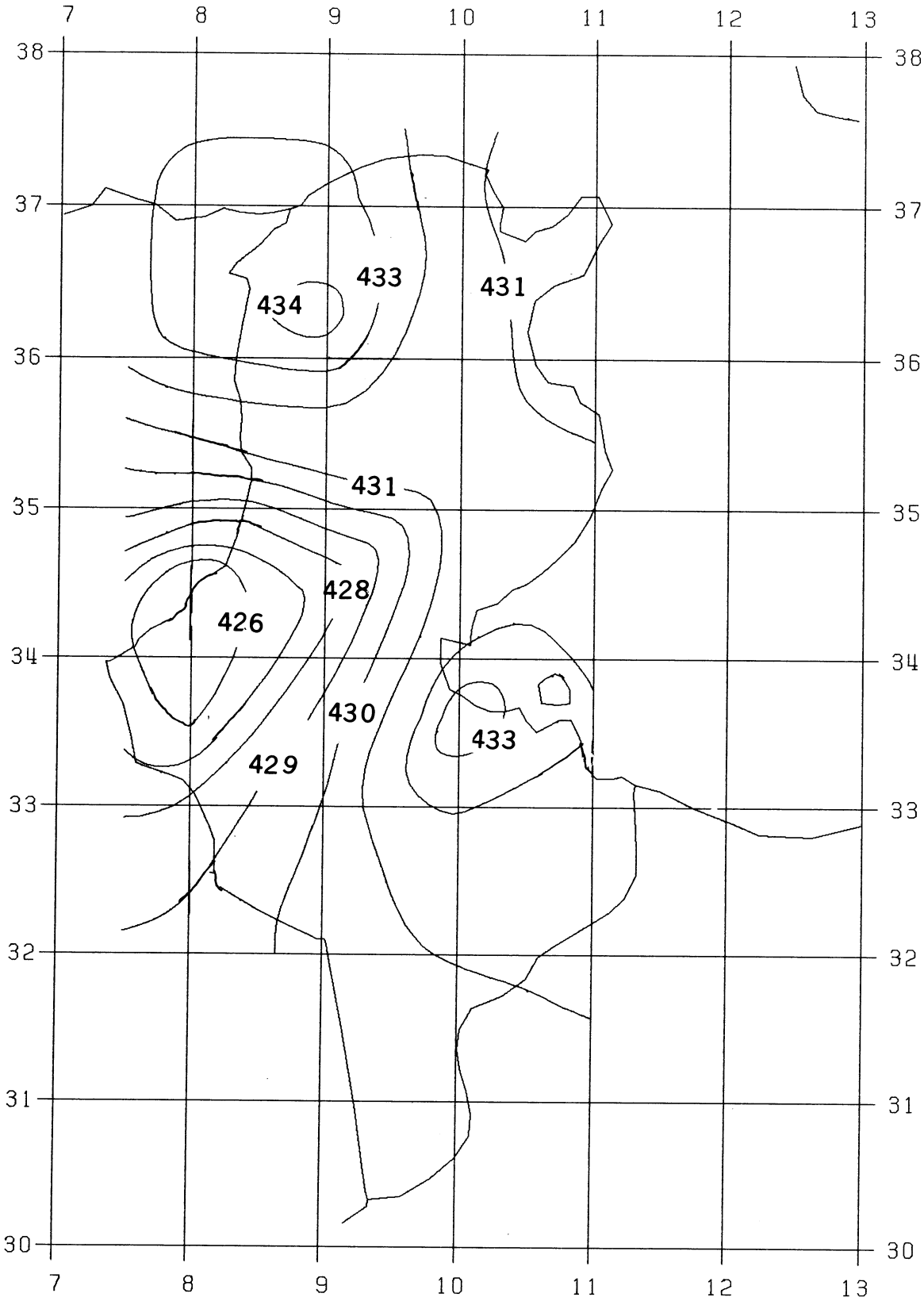

Figure 14.24. Contour Chart – Carthage Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

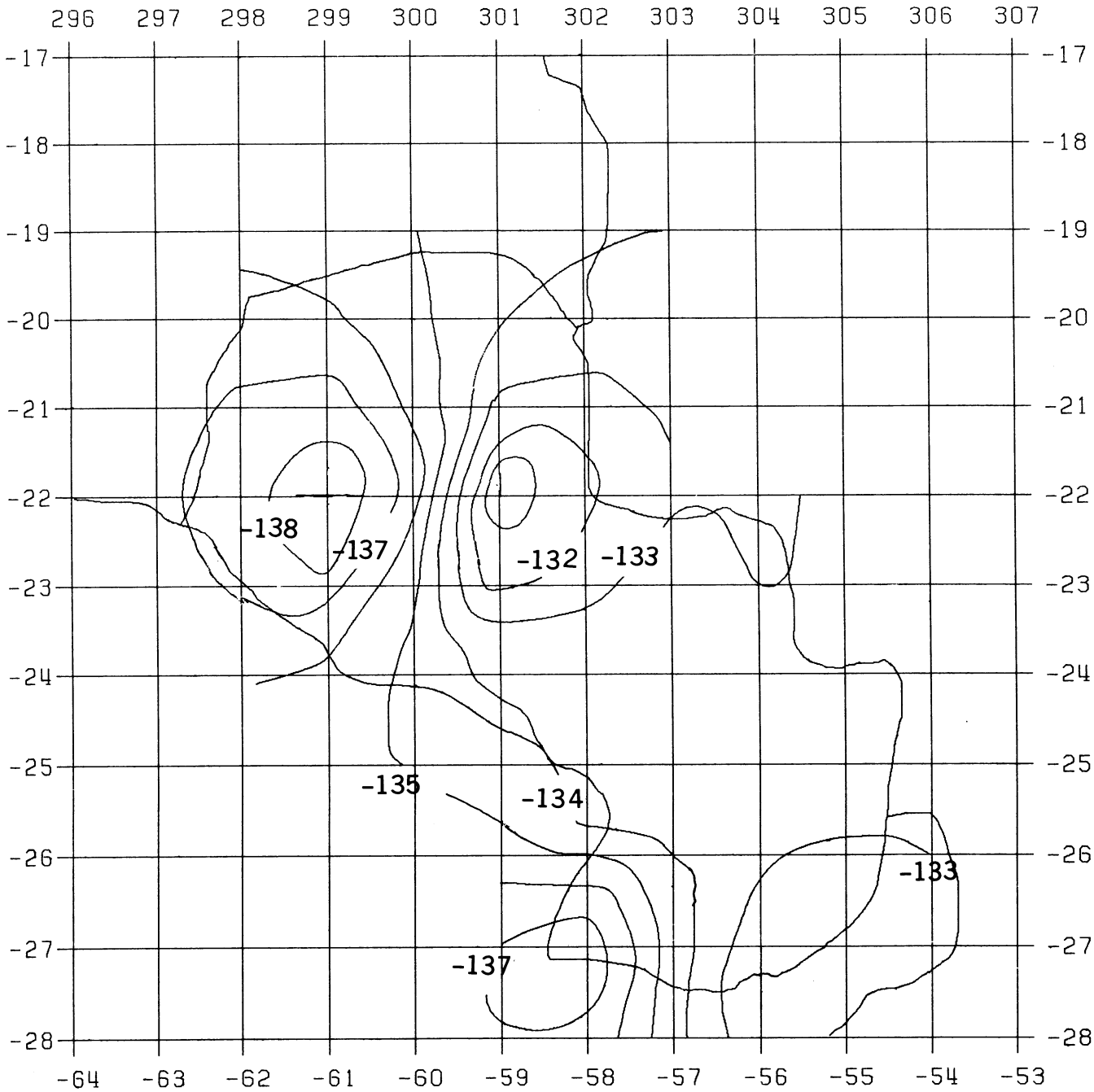

Figure 14.25. Contour Chart – Chua Astro Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

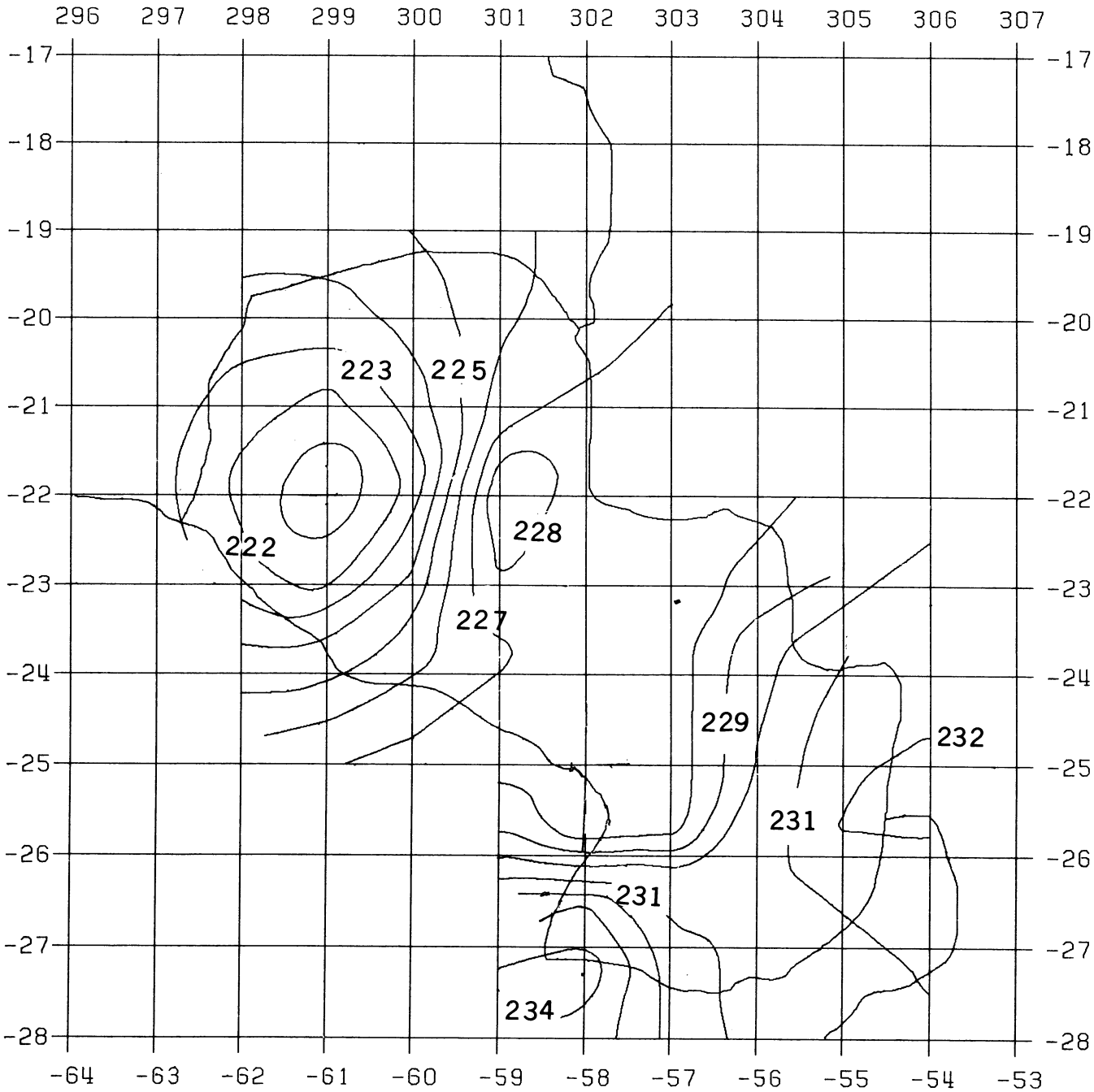

Figure 14.26. Contour Chart – Chua Astro Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

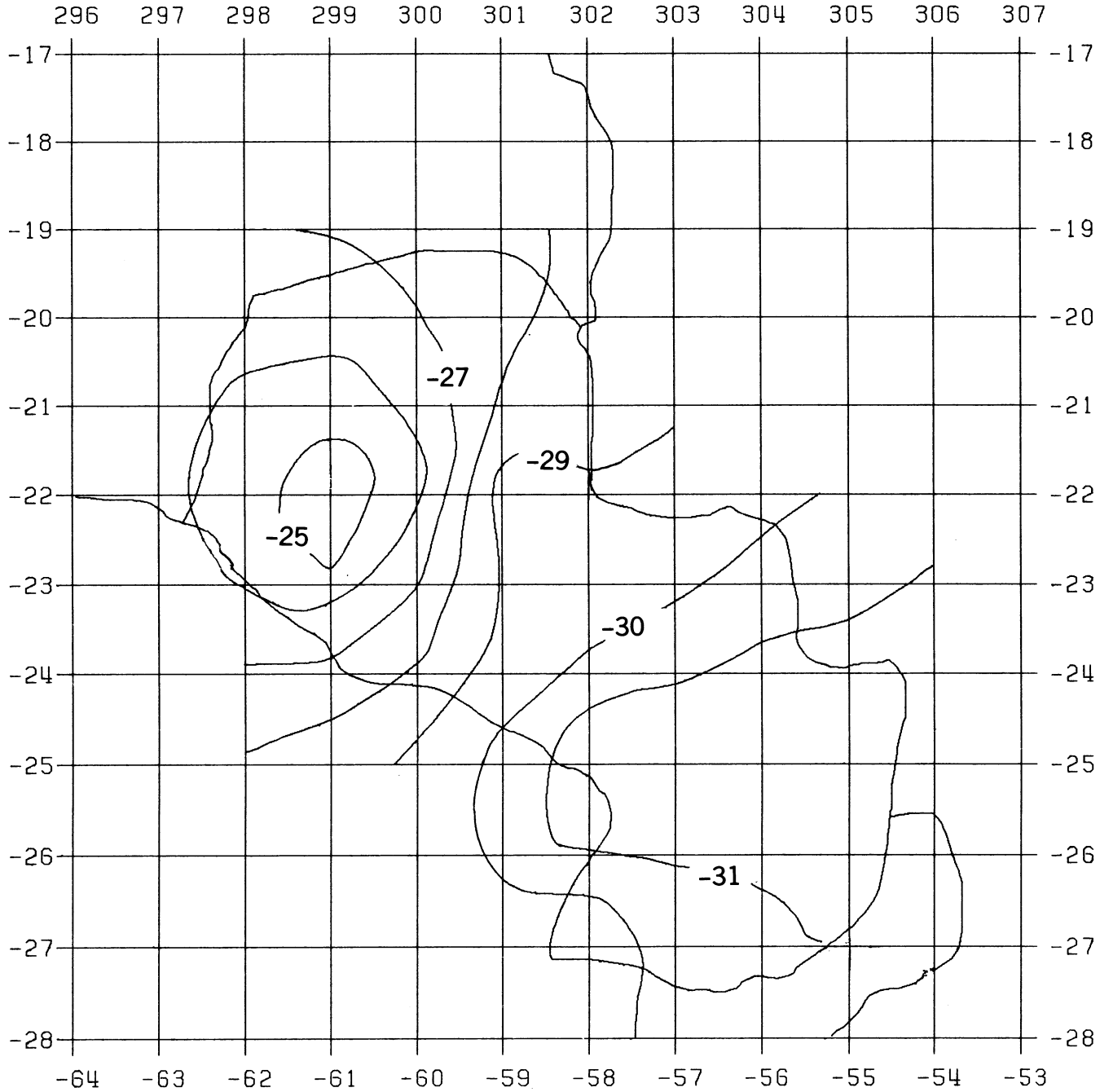

Figure 14.27. Contour Chart - Chua Astro Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

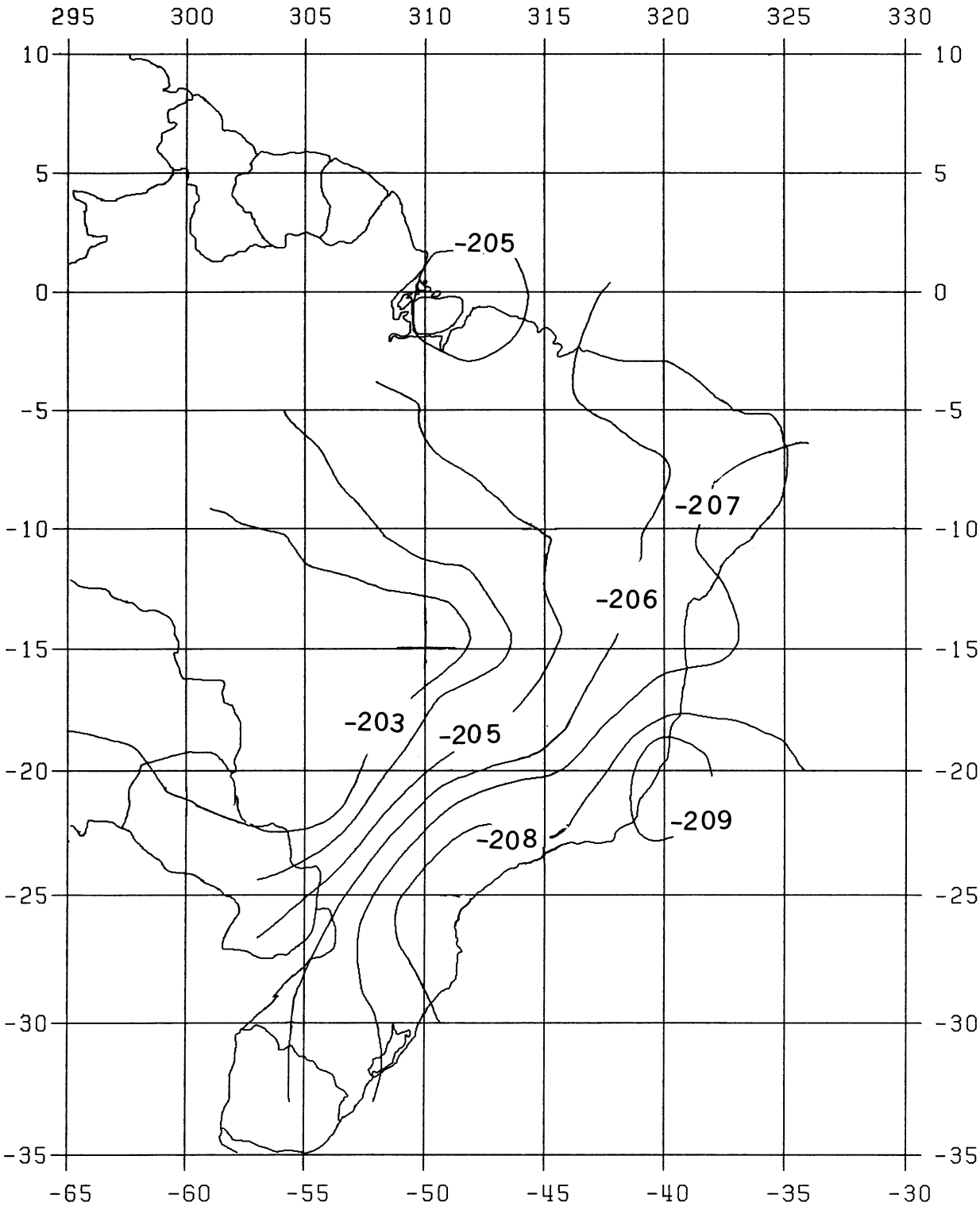

Figure 14.28. Contour Chart - Corrego Alegre Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

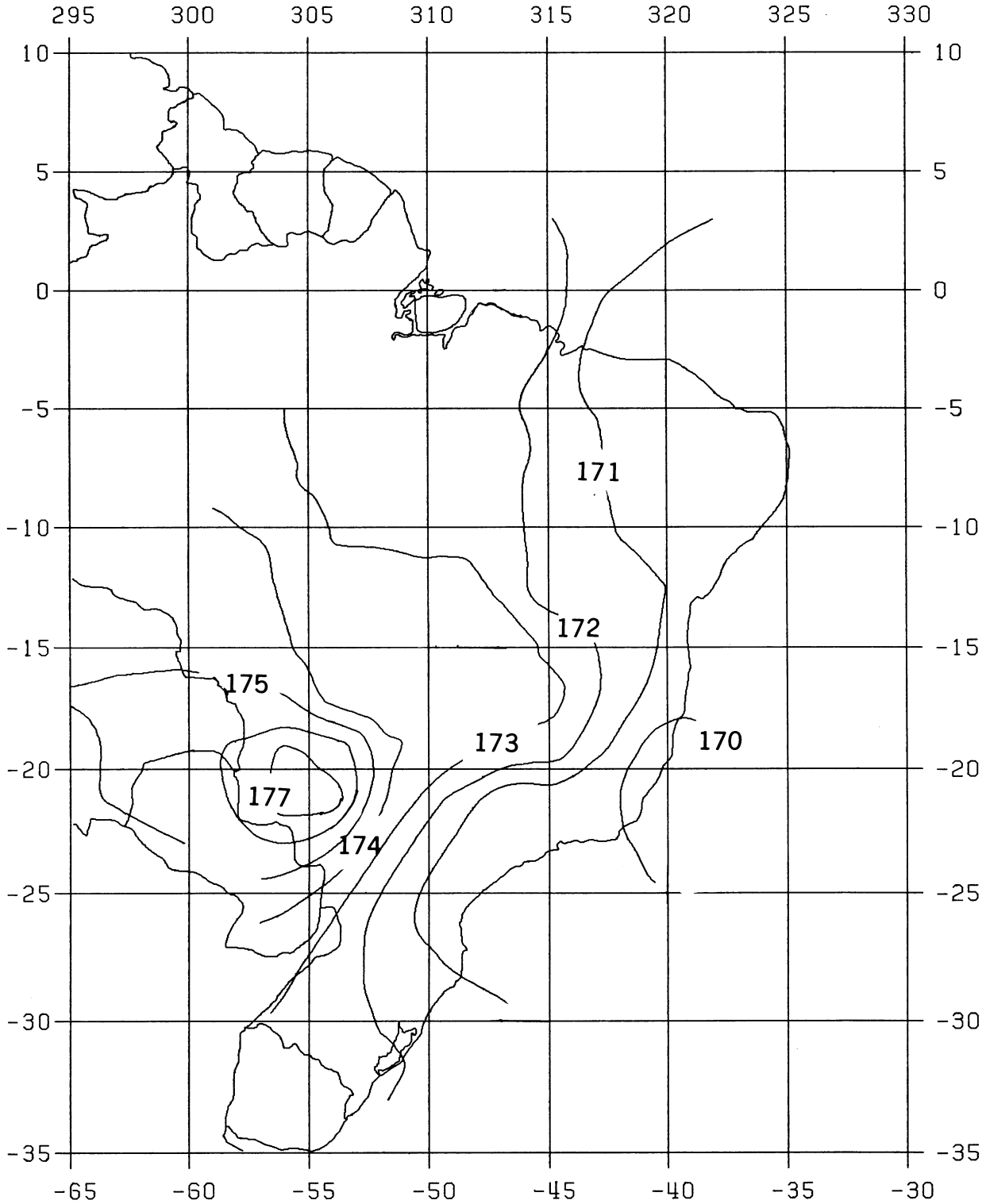

Figure 14.29. Contour Chart - Corrego Alegre Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

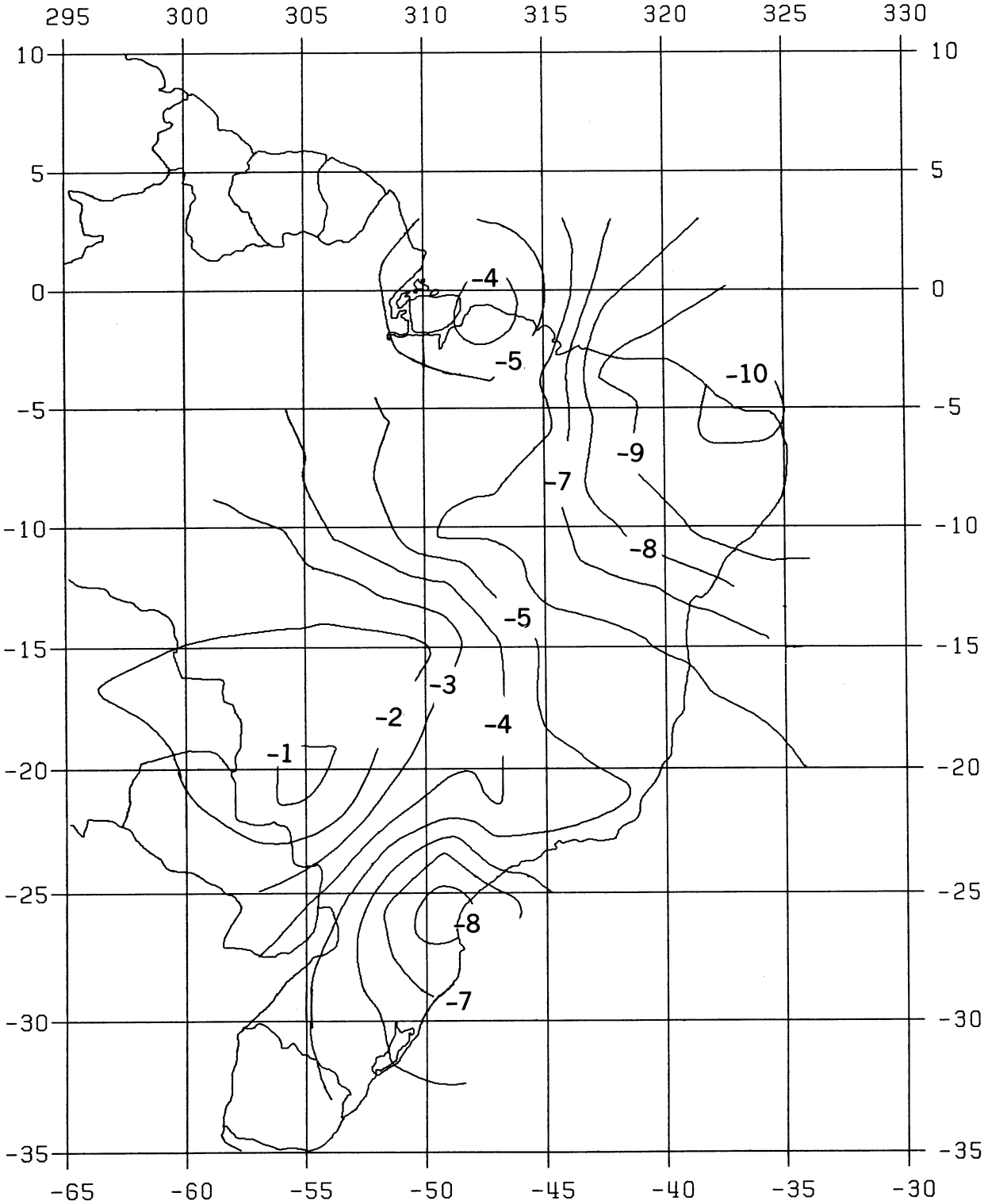

Figure 14.30. Contour Chart - Corrego Alegre Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

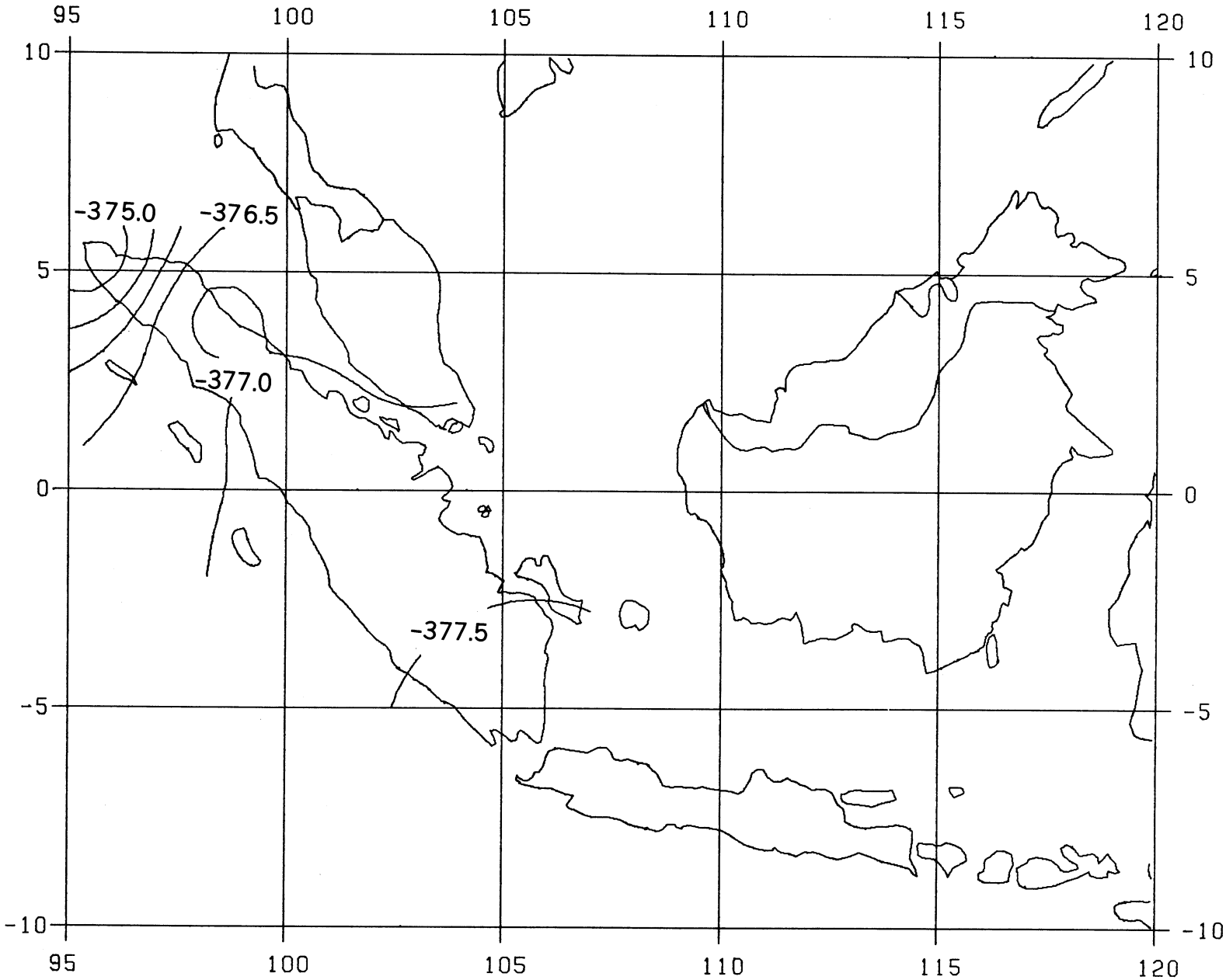

Figure 14.31. Contour Chart - Djakarta Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 0.5 Meter)

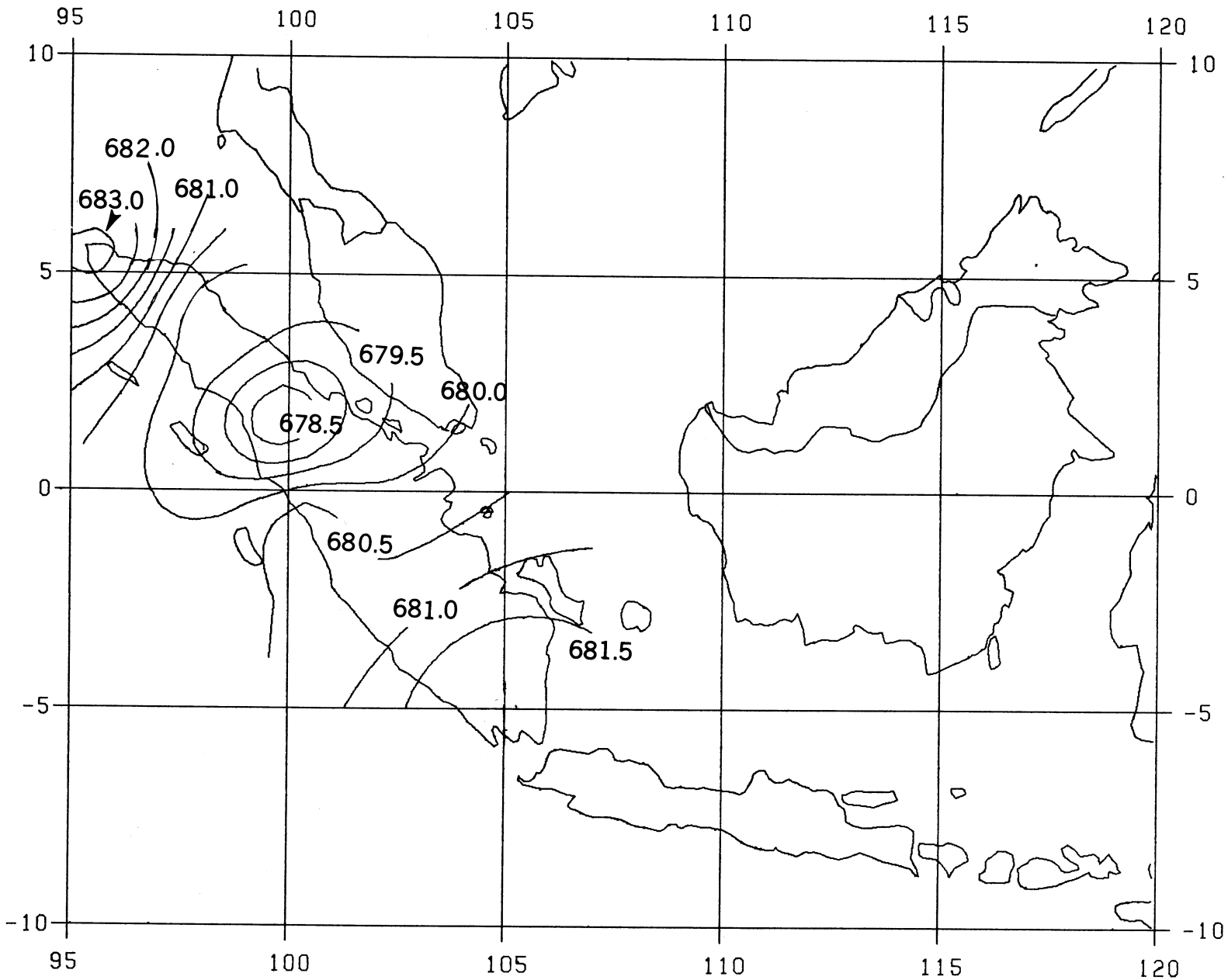

Figure 14.32. Contour Chart – Djakarta Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 0.5 Meter)

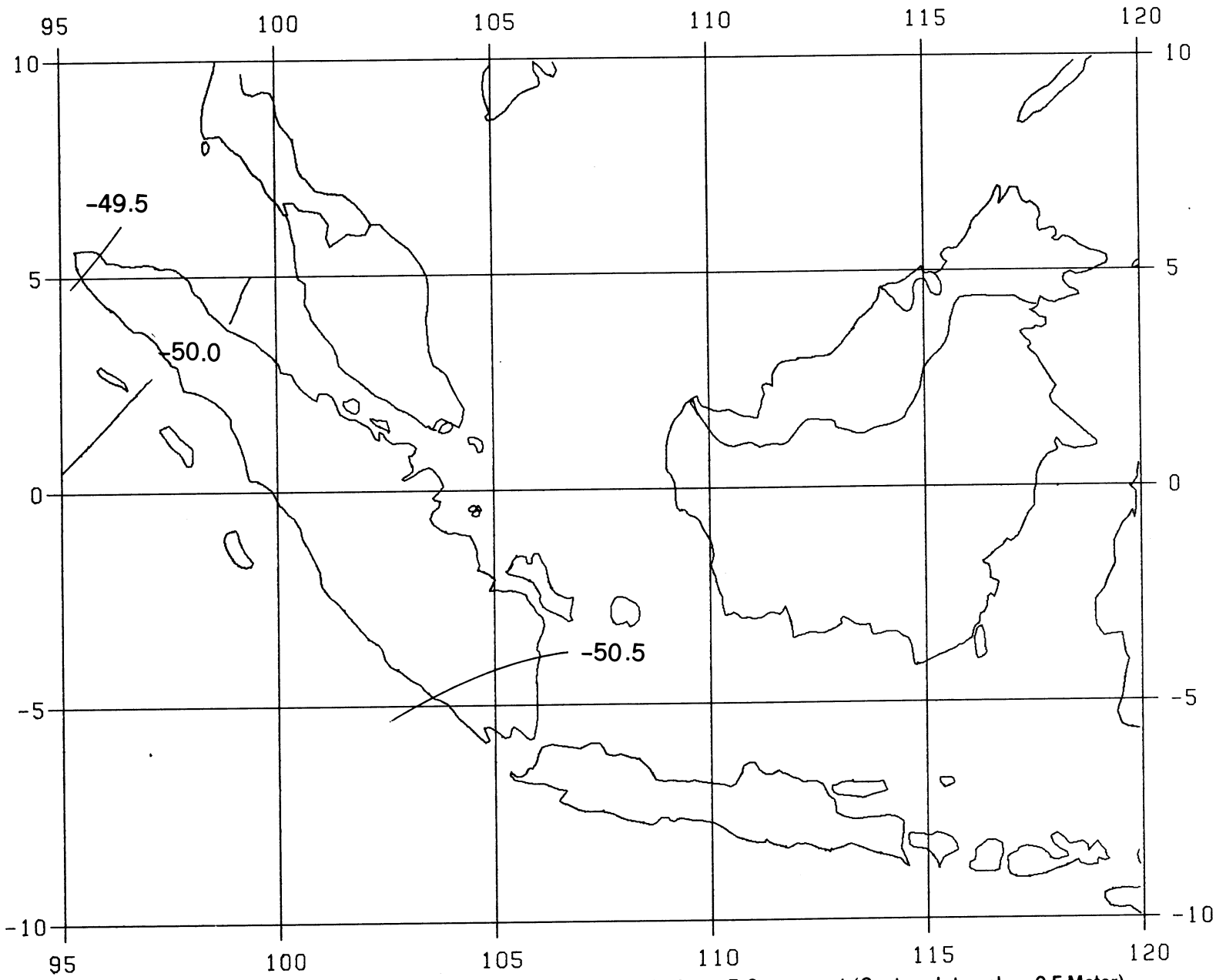

Figure 14.33. Contour Chart - Djakarta Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 0.5 Meter)

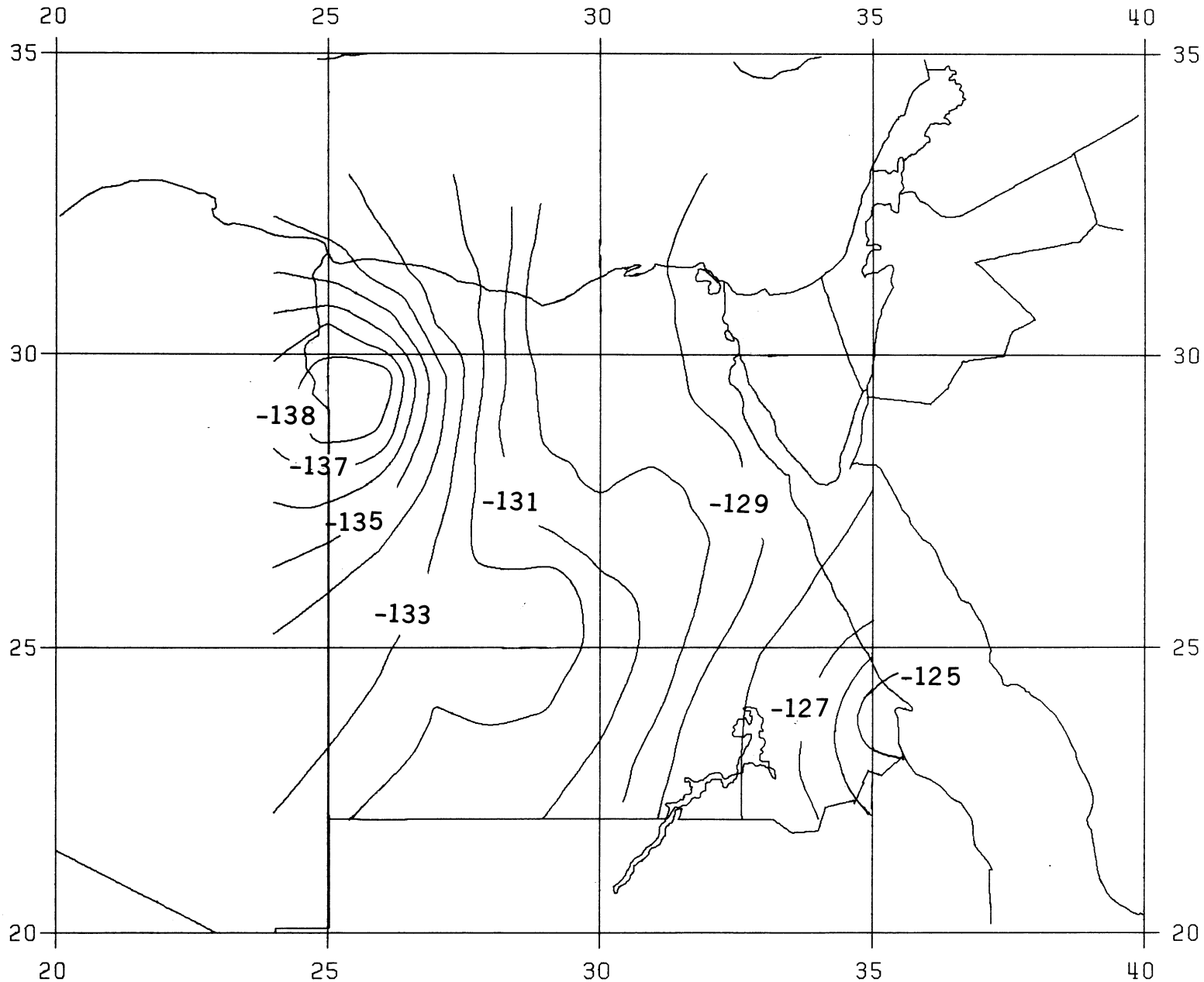

Figure 14.34. Contour Chart - ED 50 (Egypt) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

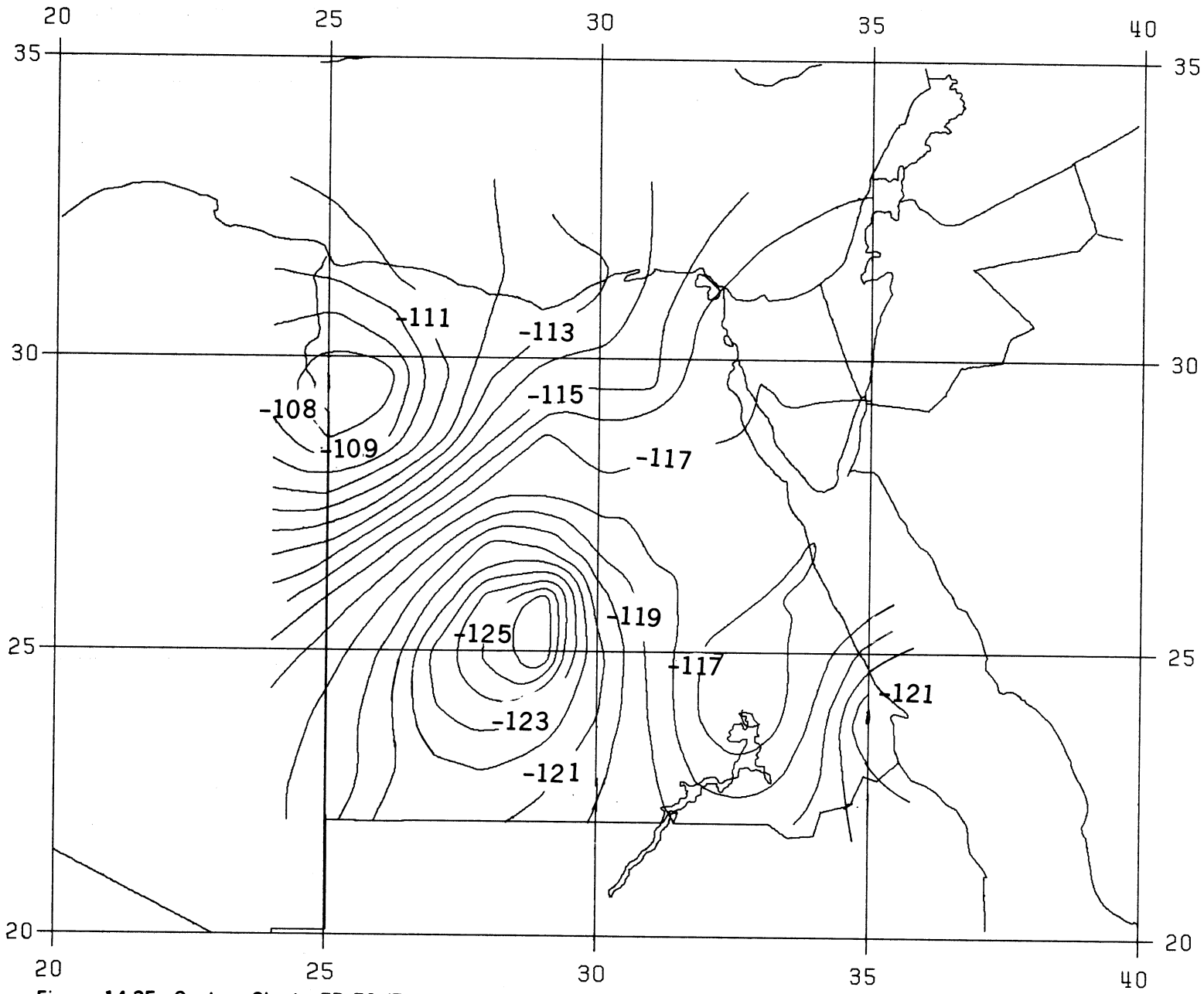

Figure 14.35. Contour Chart - ED 50 (Egypt) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

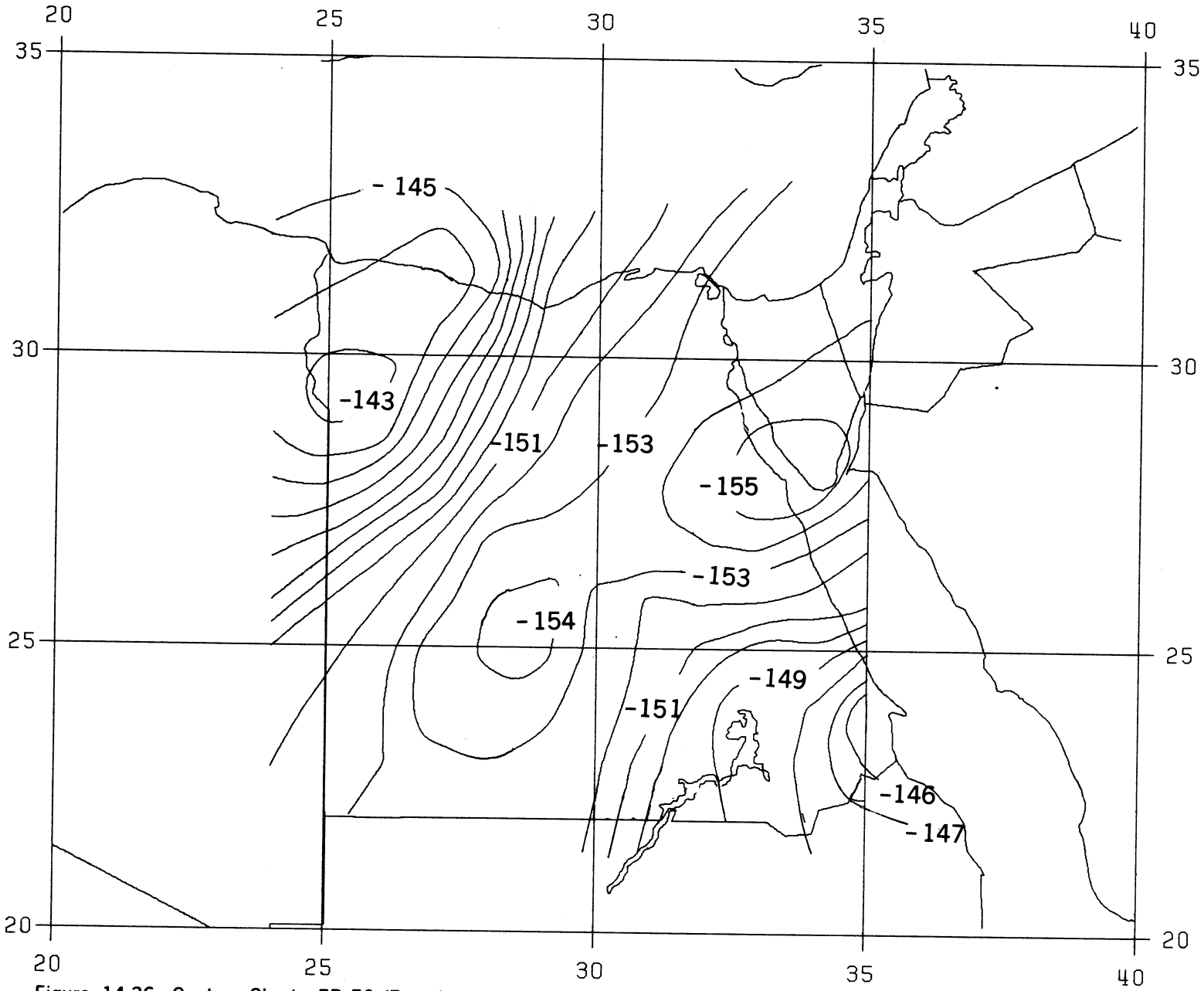

Figure 14.36. Contour Chart – ED 50 (Egypt) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

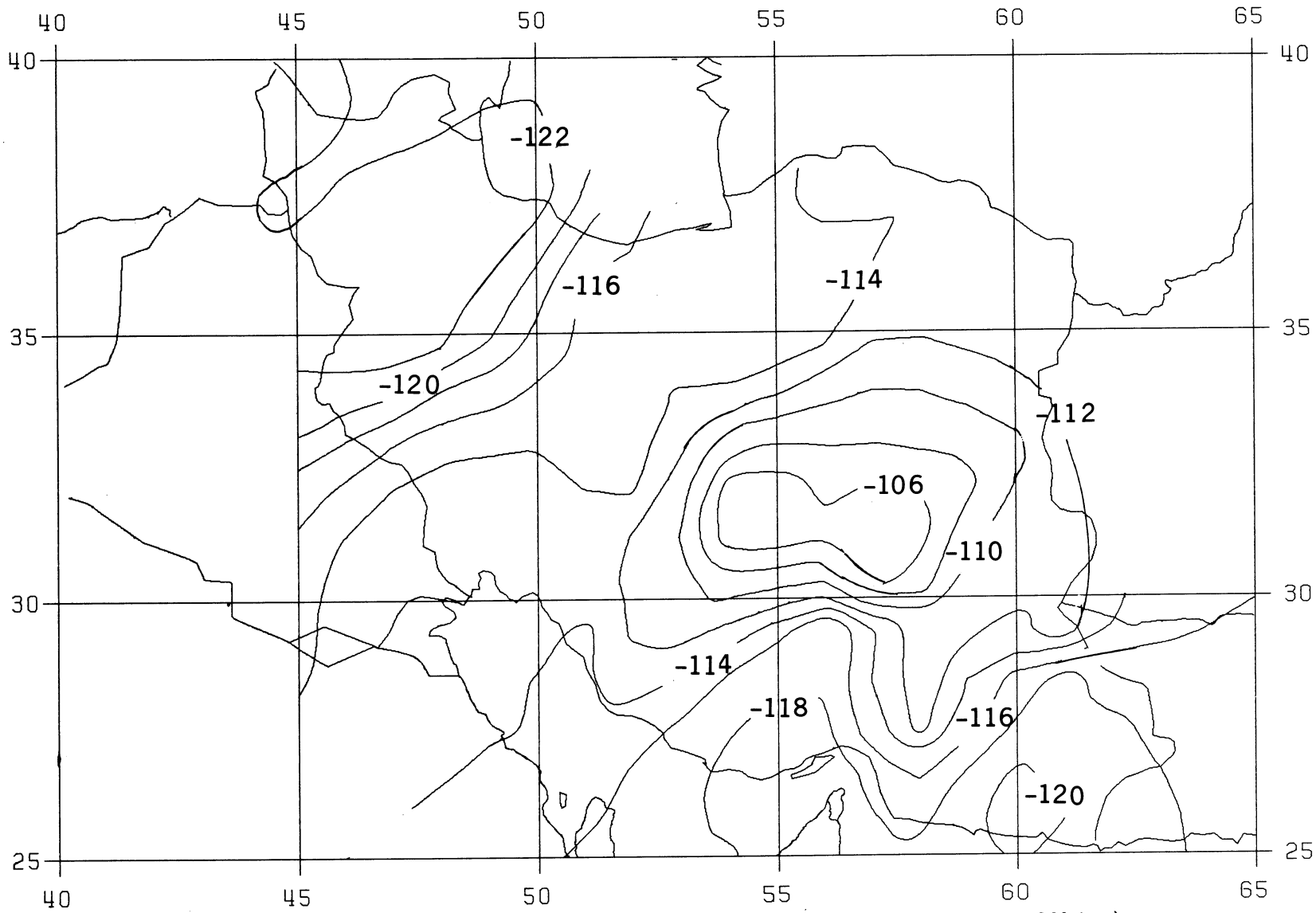

Figure 14.37. Contour Chart - ED 50 (Iran) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 2 Meters)

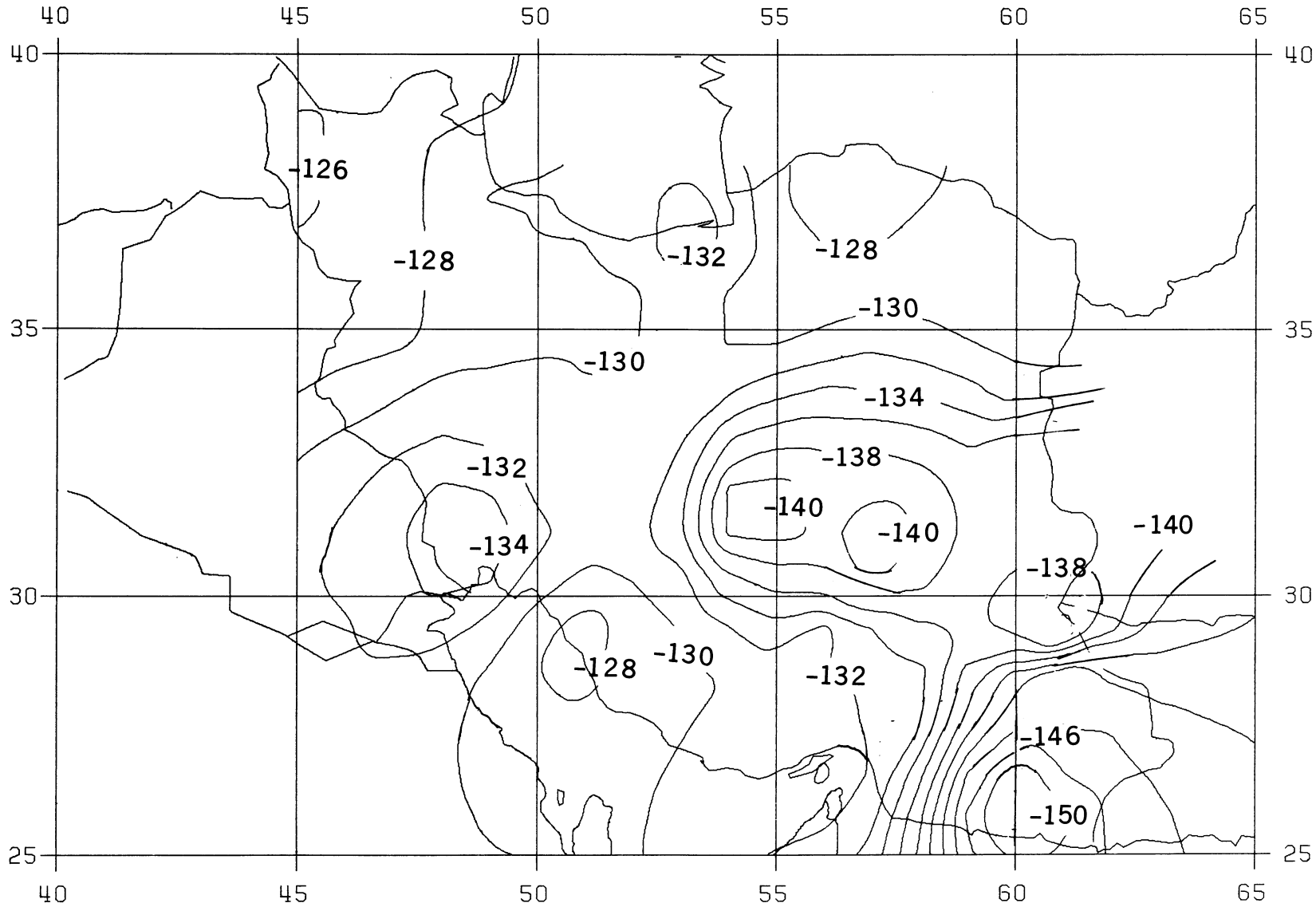

Figure 14.38. Contour Chart - ED 50 (Iran) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 2 Meters)

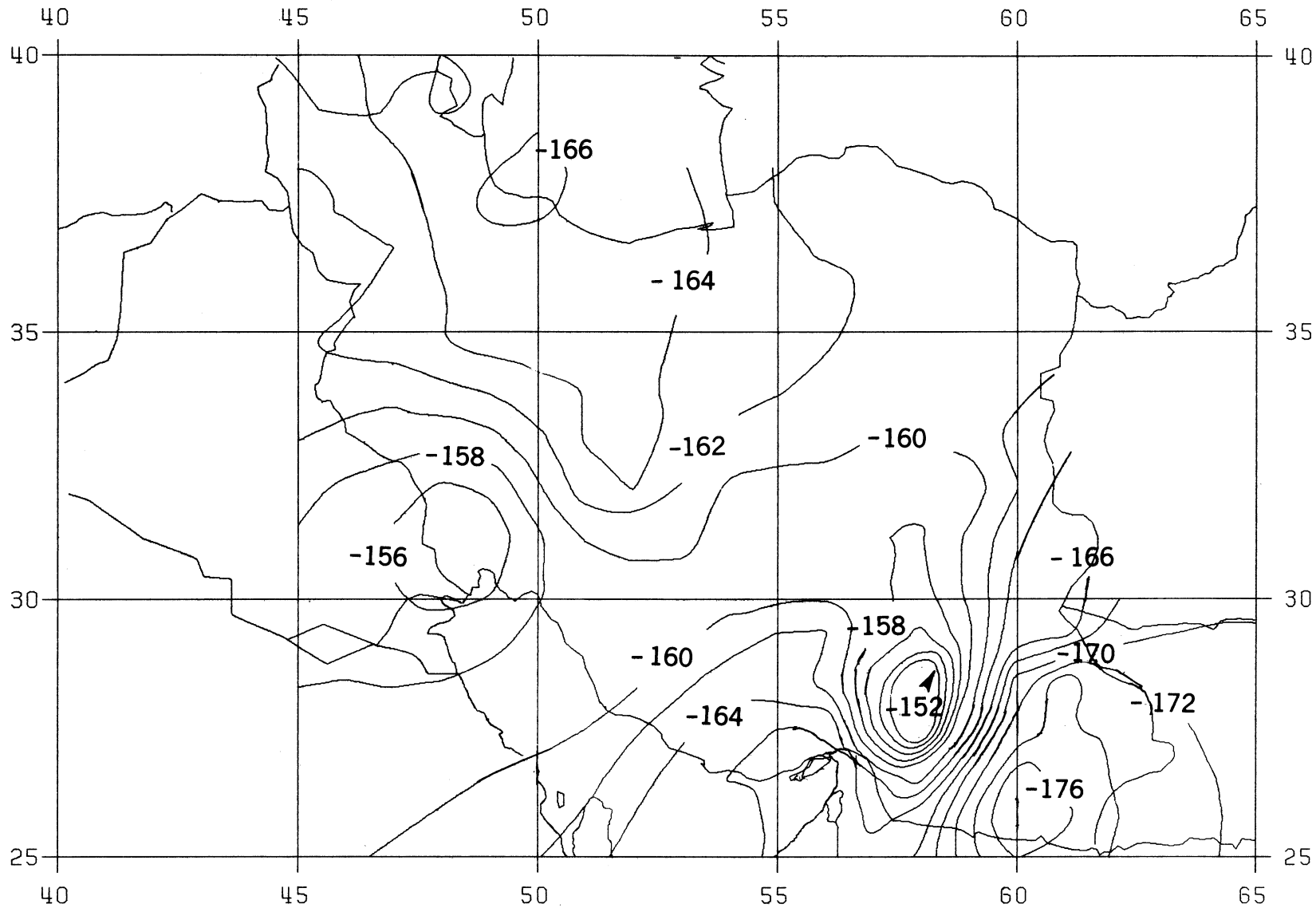

Figure 14.39. Contour Chart - ED 50 (Iran) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 2 Meters)

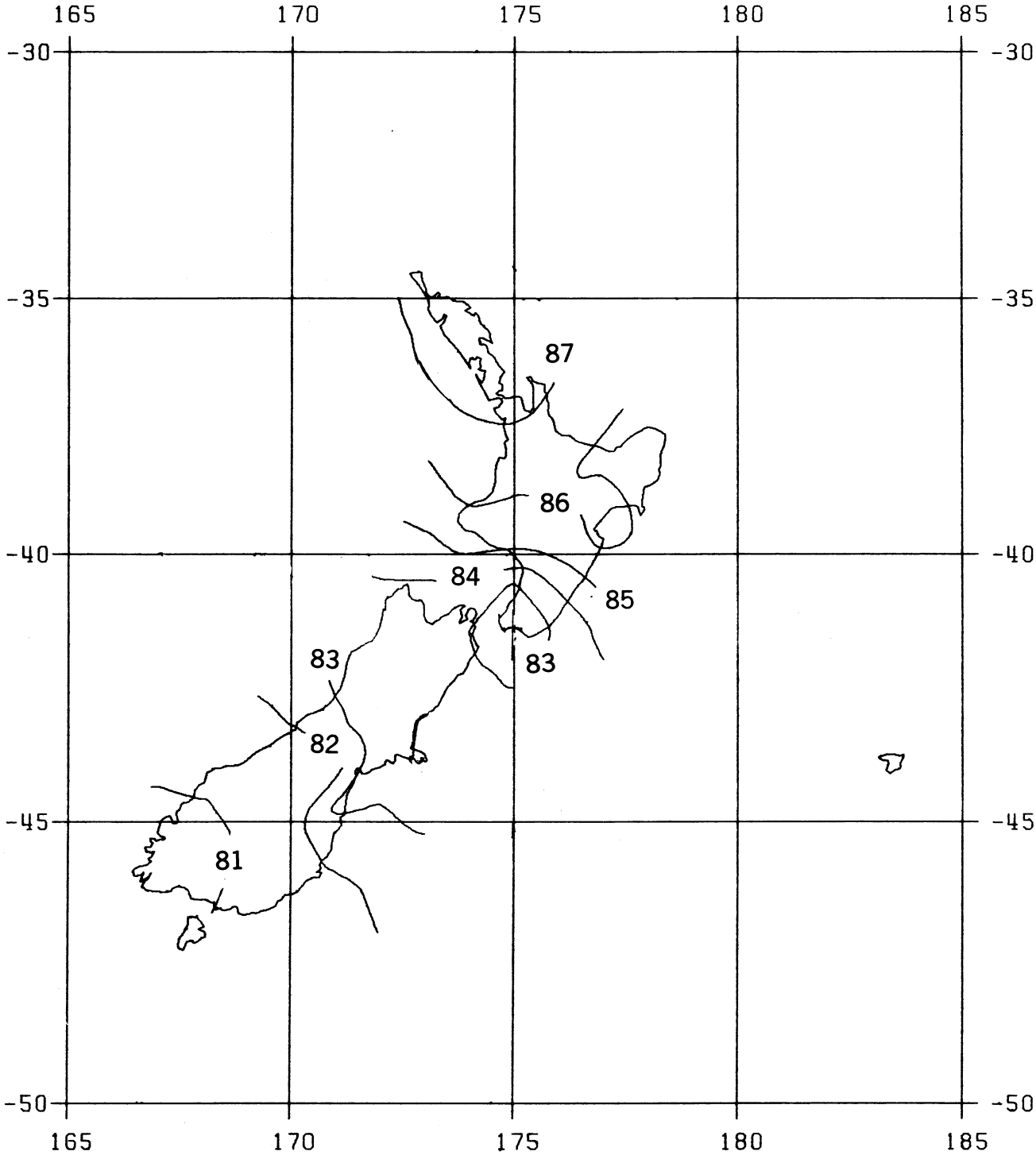

Figure 14.40. Contour Chart - Geodetic Datum 1949 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

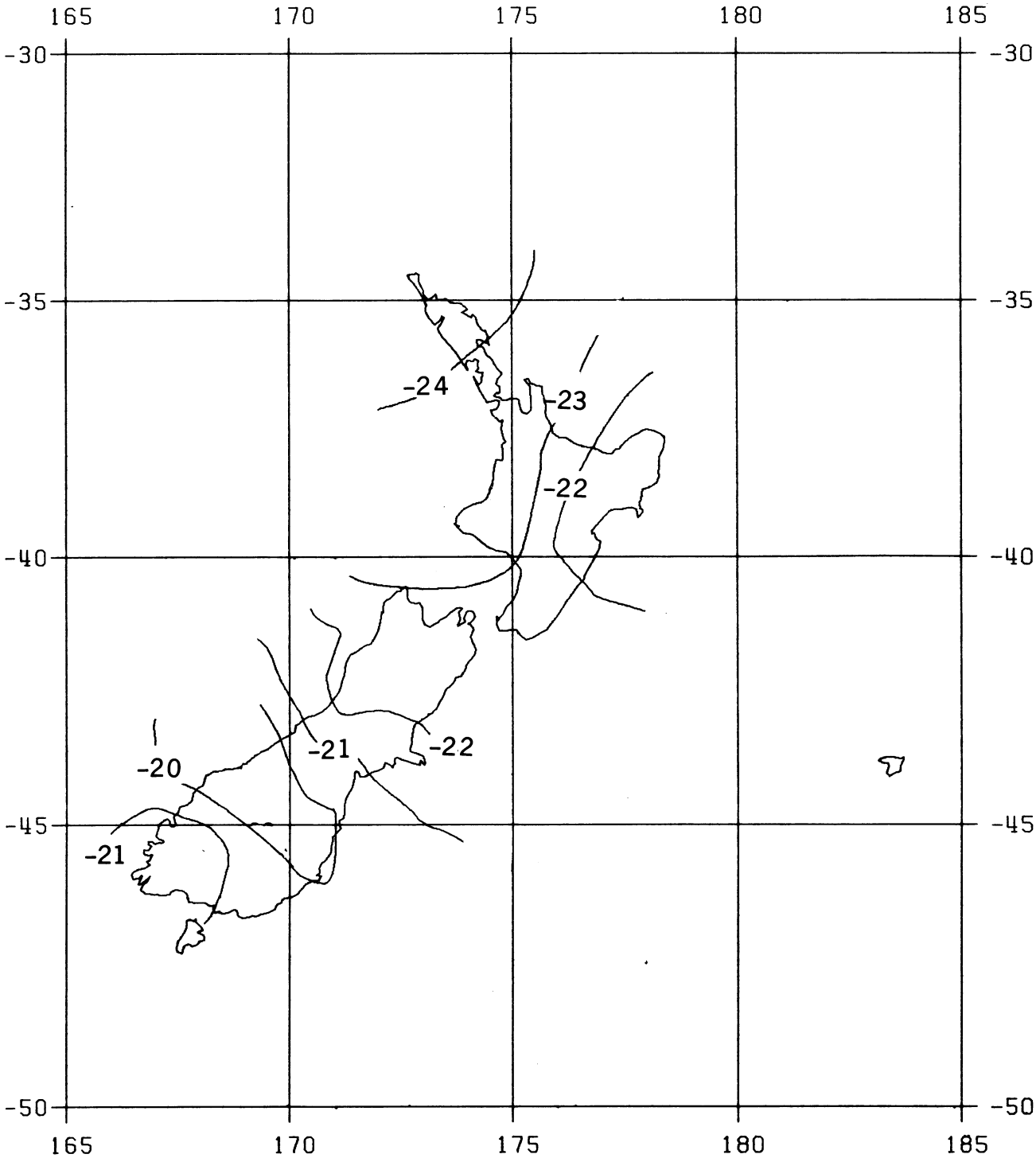

Figure 14.41. Contour Chart - Geodetic Datum 1949 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

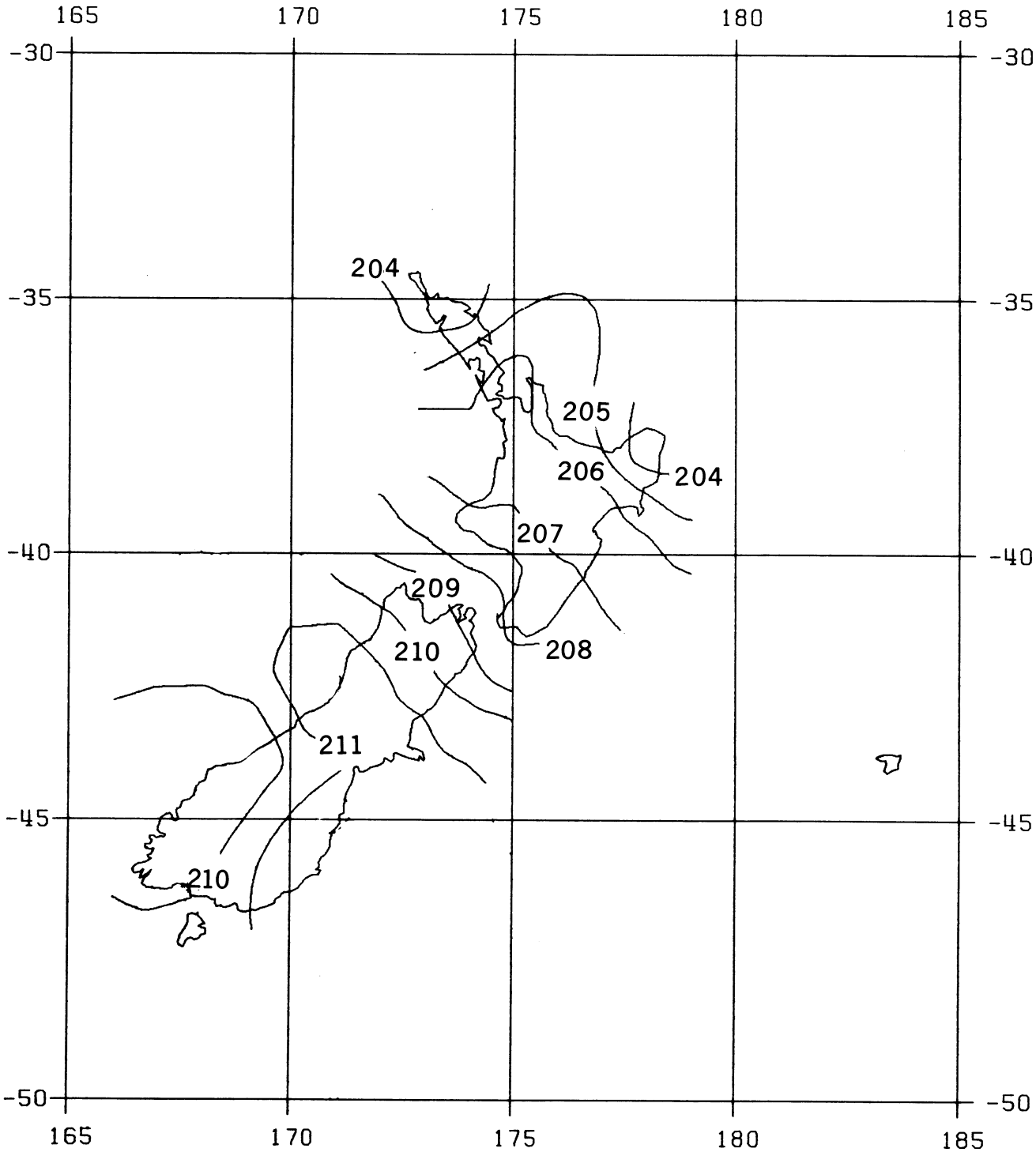

Figure 14.42. Contour Chart - Geodetic Datum 1949 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

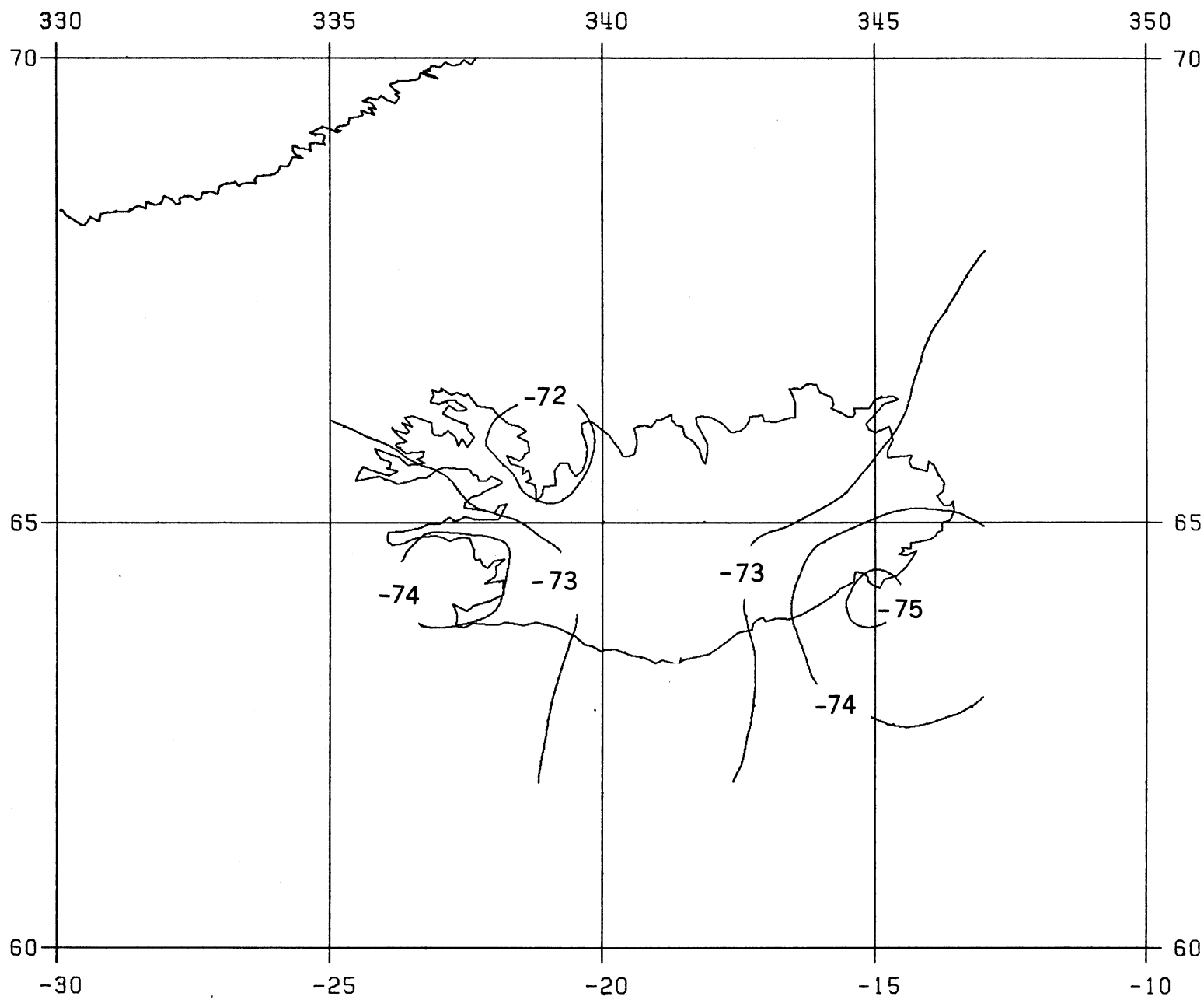

Figure 14.43. Contour Chart - Hjorsey Datum 1955 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

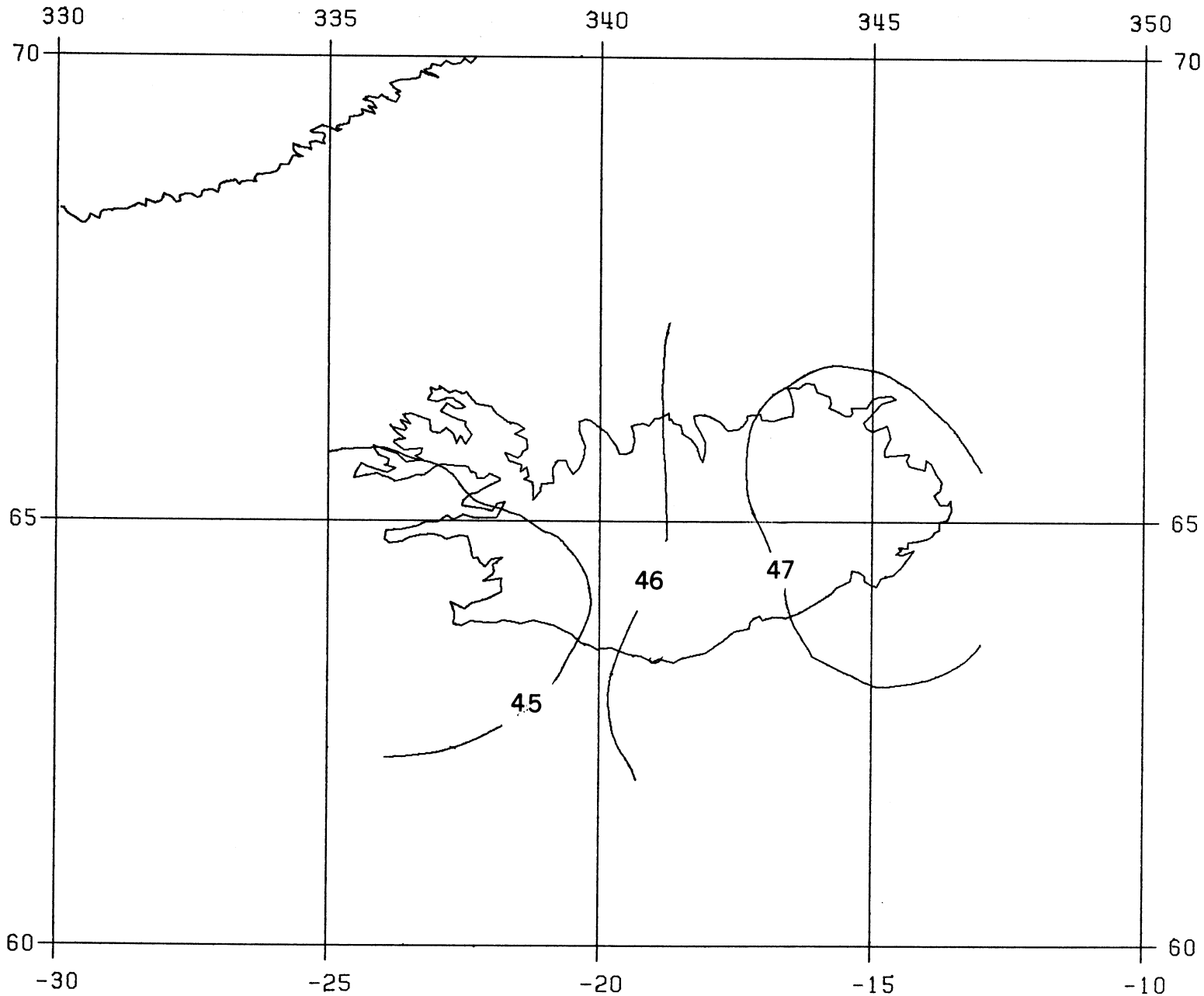

Figure 14.44. Contour Chart - Hjorsey Datum 1955 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

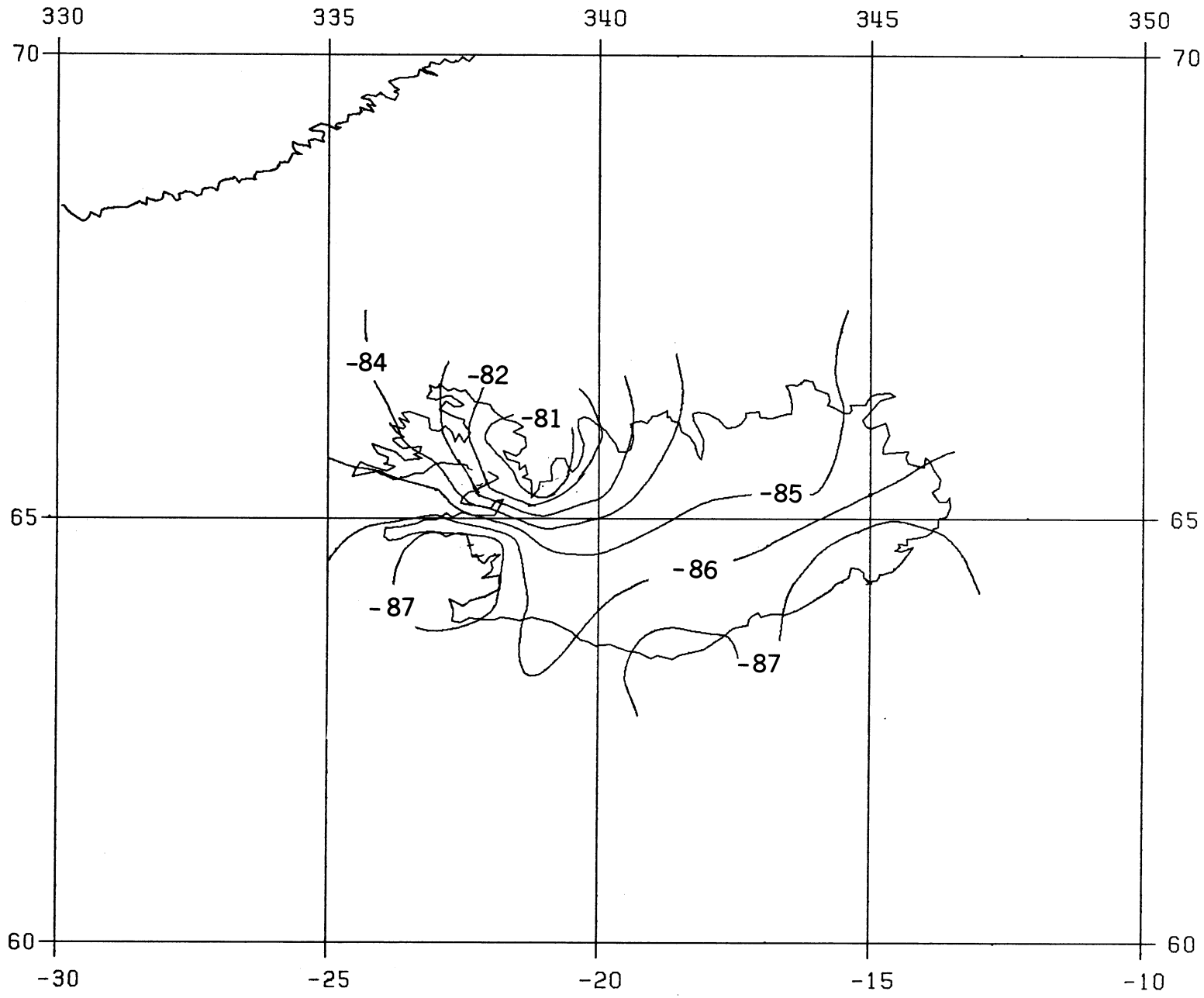

Figure 14.45. Contour Chart - Hjorsey Datum 1955 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

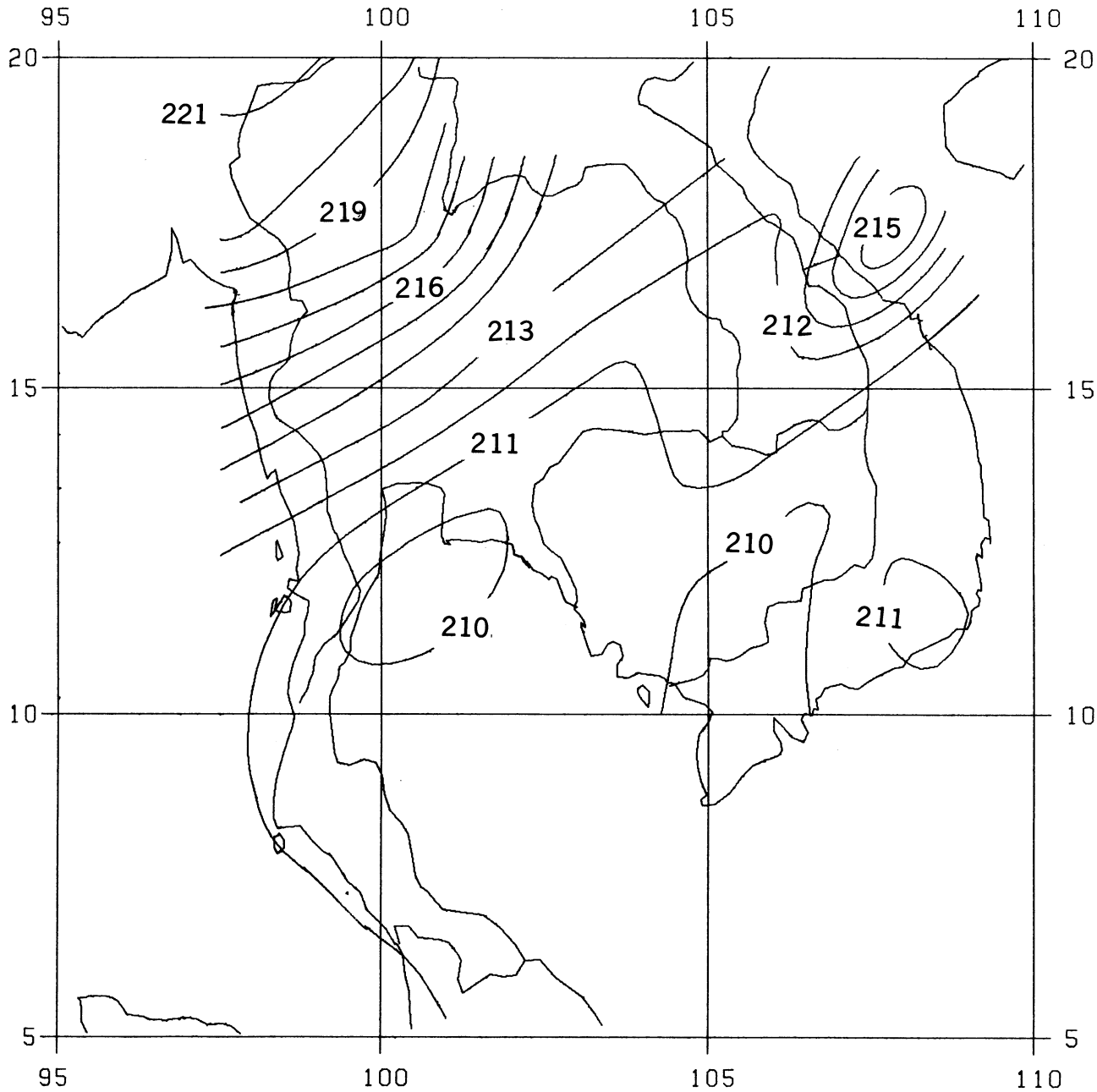

Figure 14.46. Contour Chart - Indian Datum to WGS 84 Datum Shifts, △X Component (Contour Interval = 1 Meter)

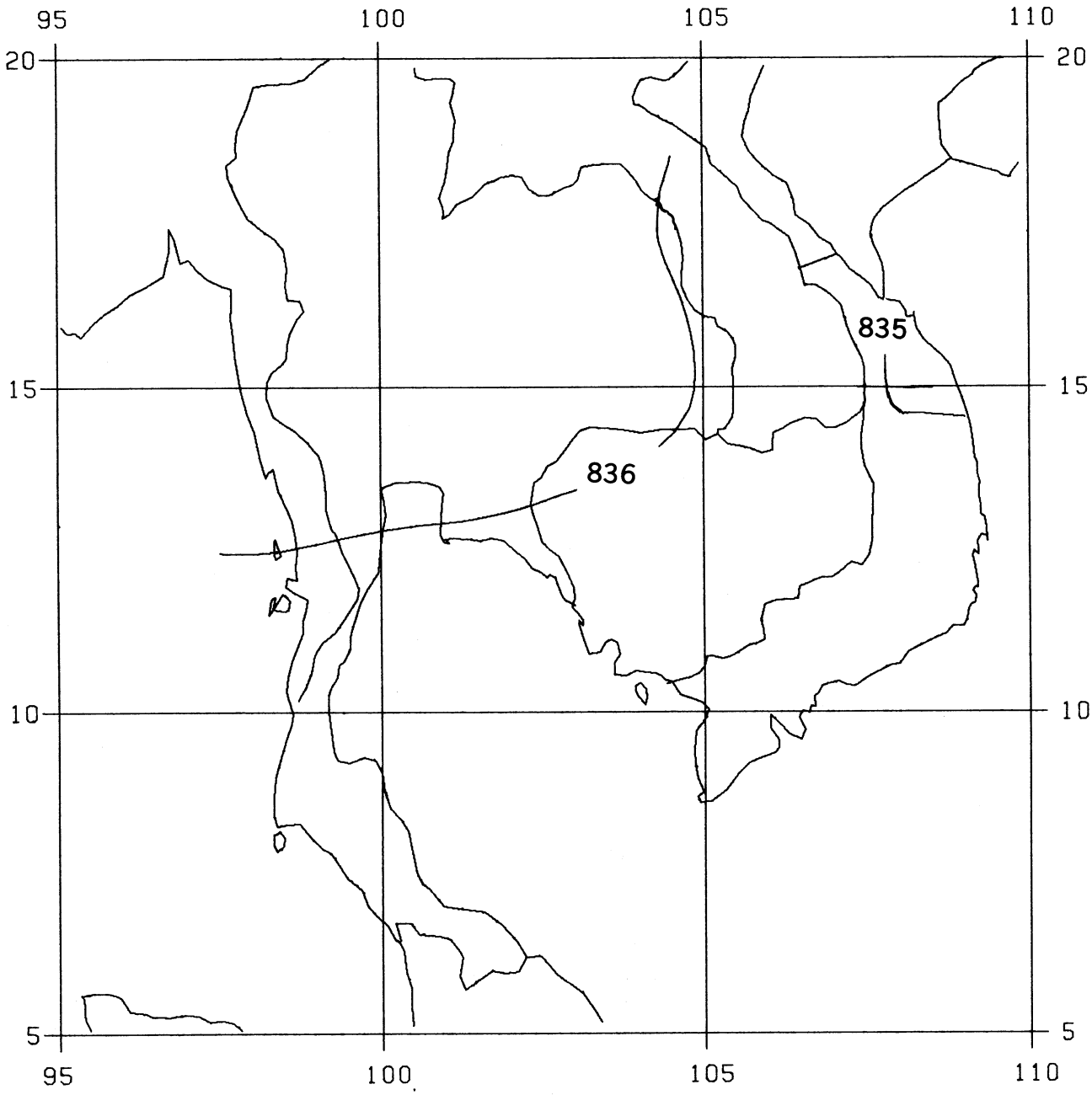

Figure 14.47. Contour Chart – Indian Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

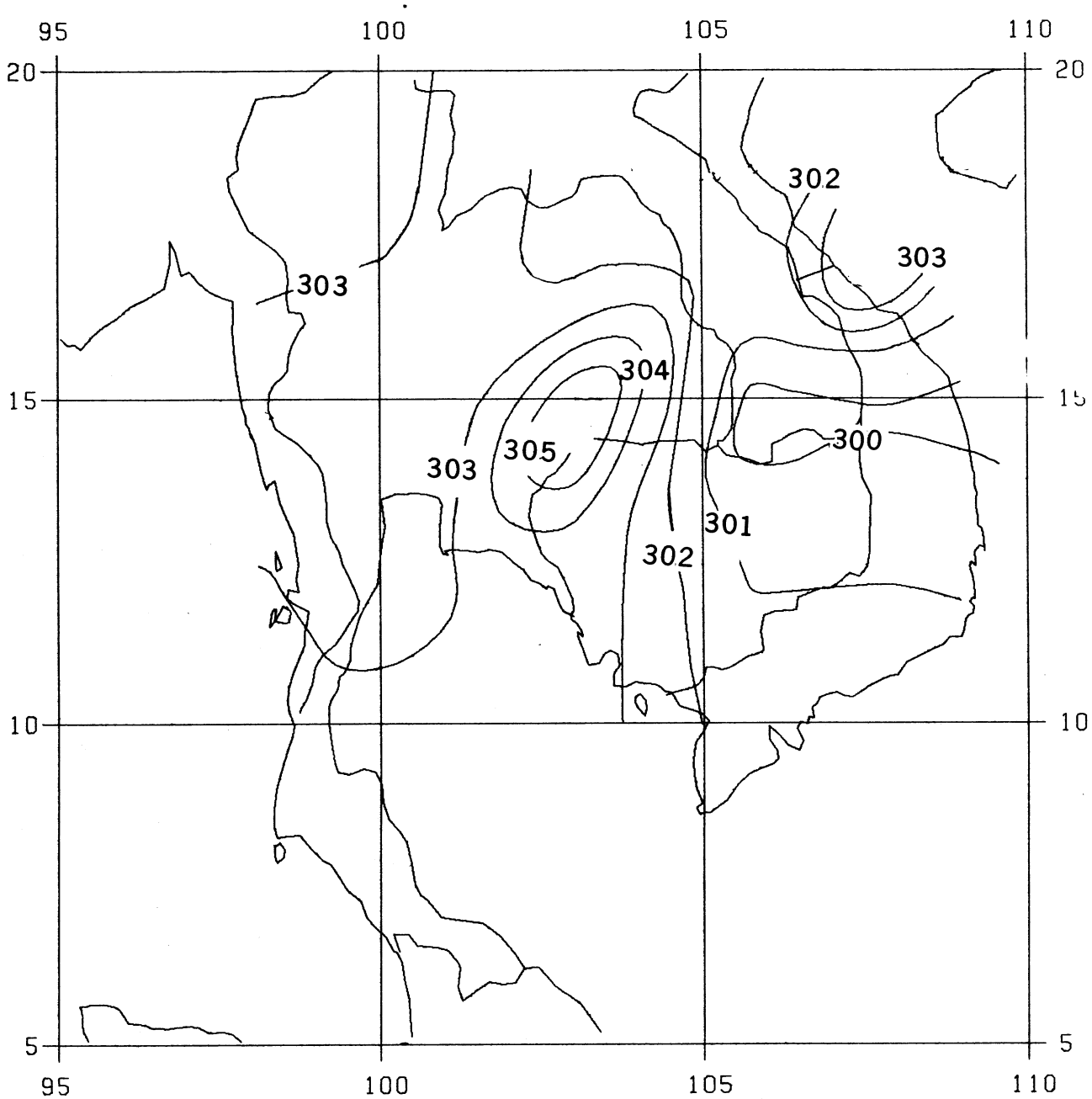

Figure 14.48. Contour Chart – Indian Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

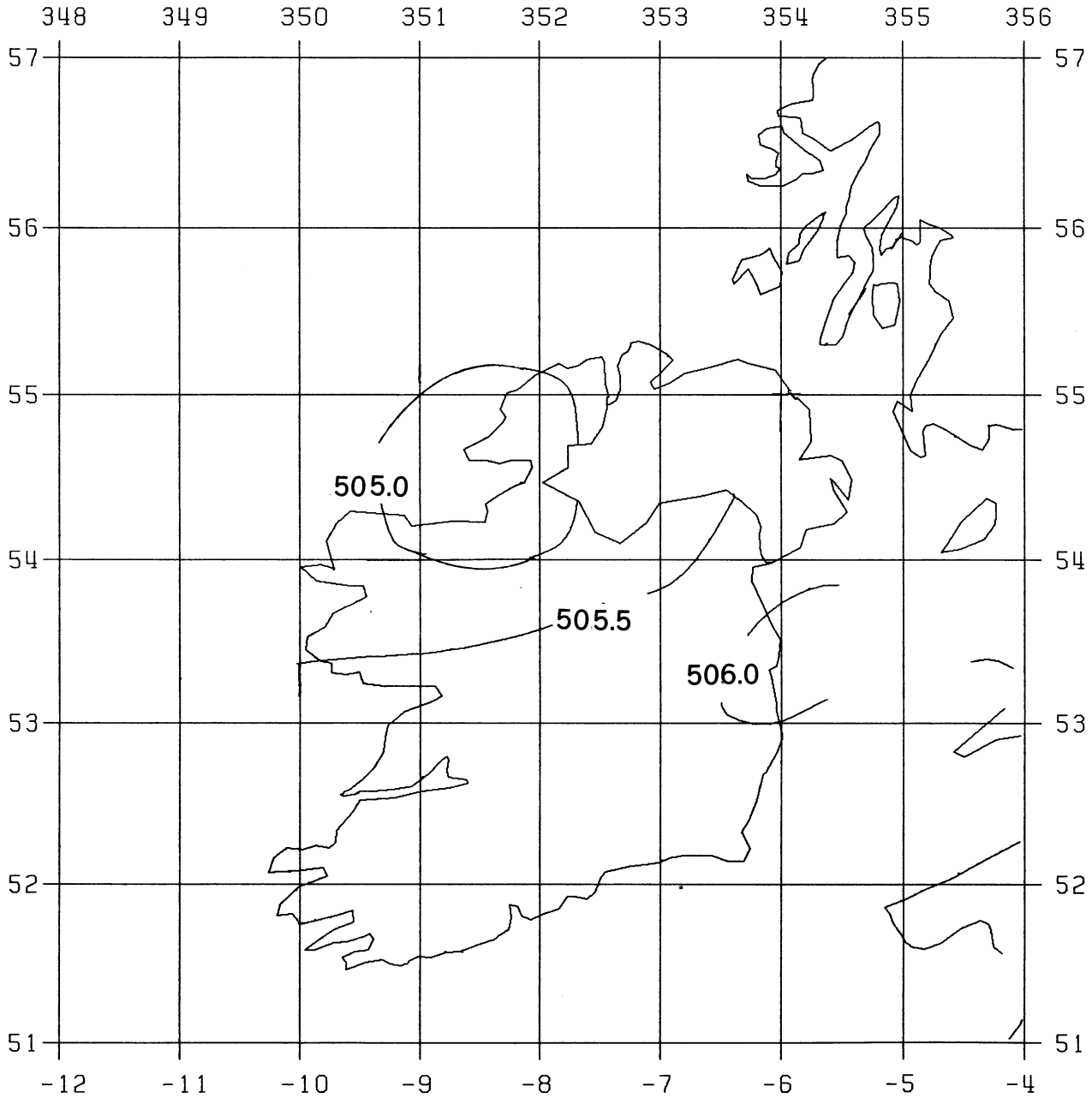

Figure 14.49. Contour Chart - Ireland Datum 1965 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 0.5 Meter)

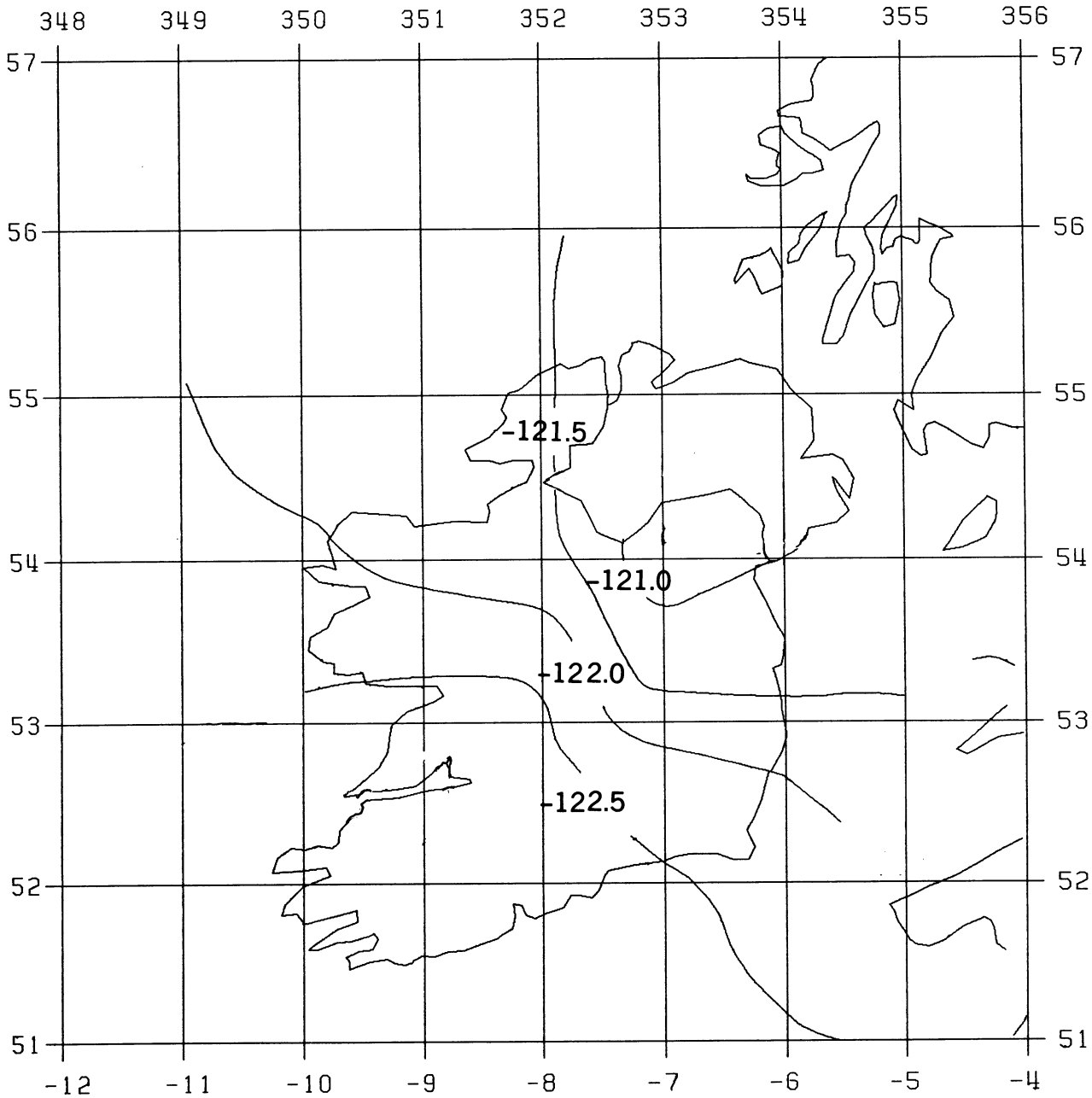

Figure 14.50. Contour Chart – Ireland Datum 1965 to WGS 84 Datum Shifts, △Y Component (Contour Interval = 0.5 Meter)

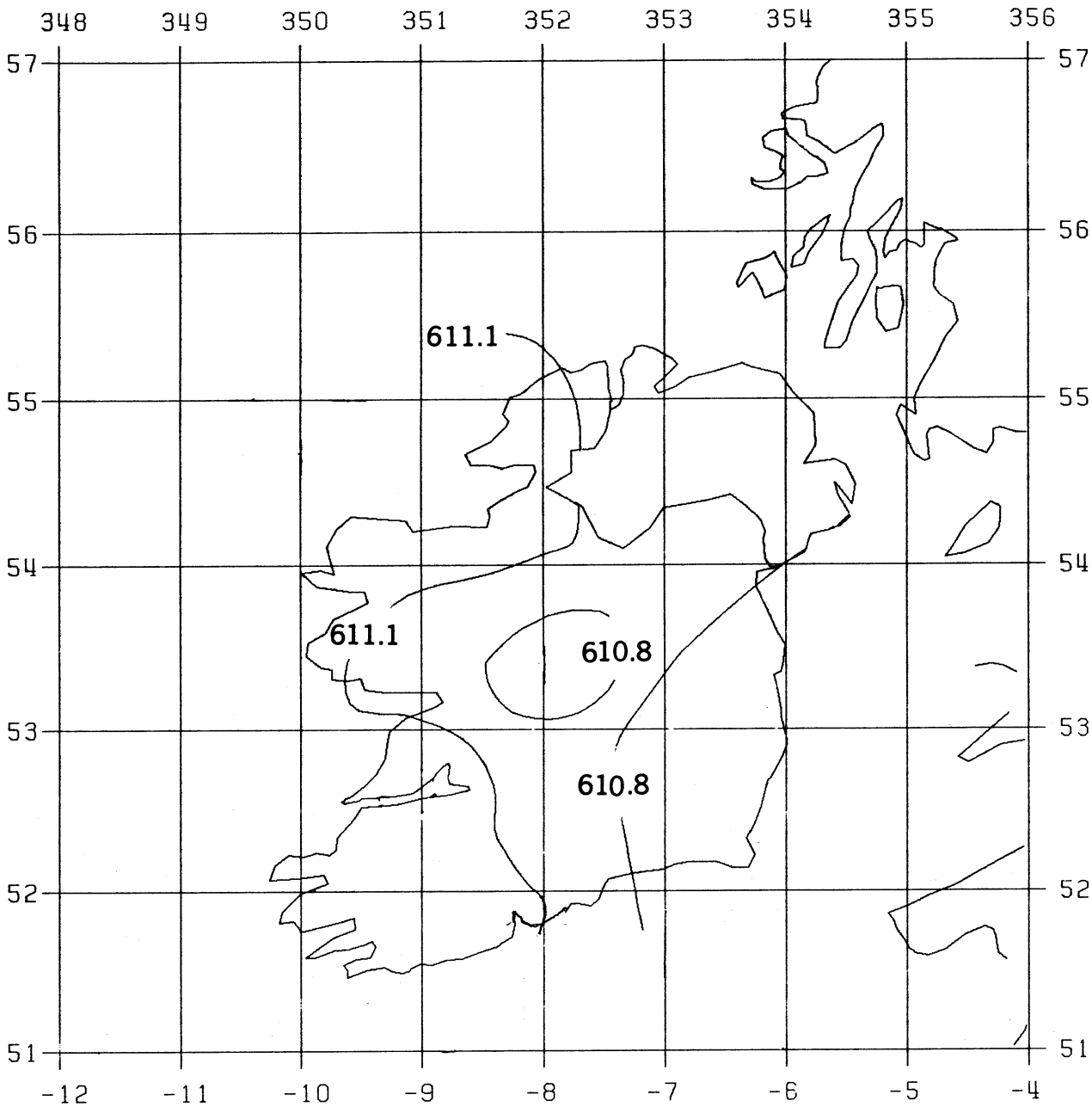

Figure 14.51. Contour Chart – Ireland Datum 1965 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 0.3 Meter)

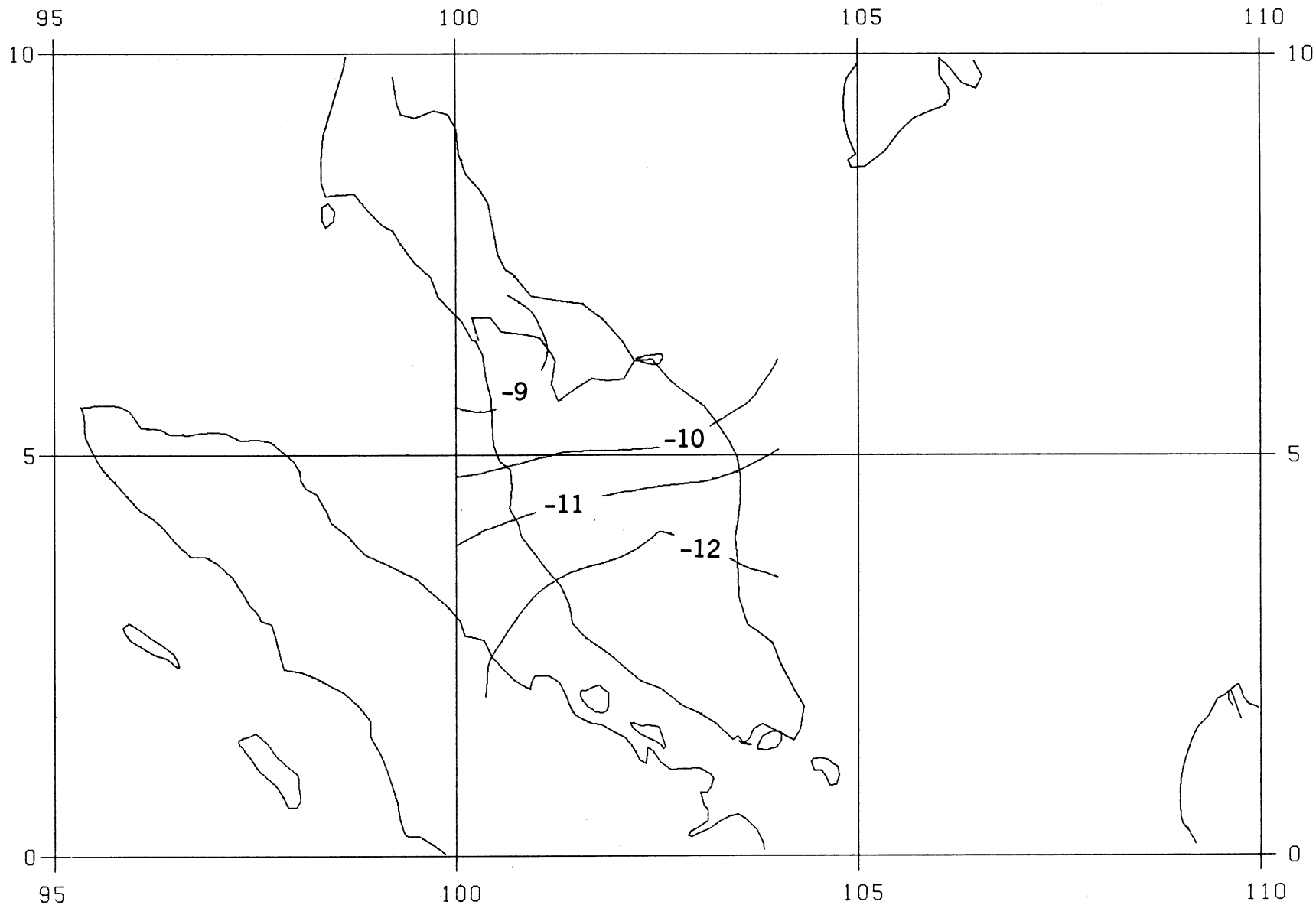

Figure 14.52. Contour Chart – Kertau Datum 1948 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

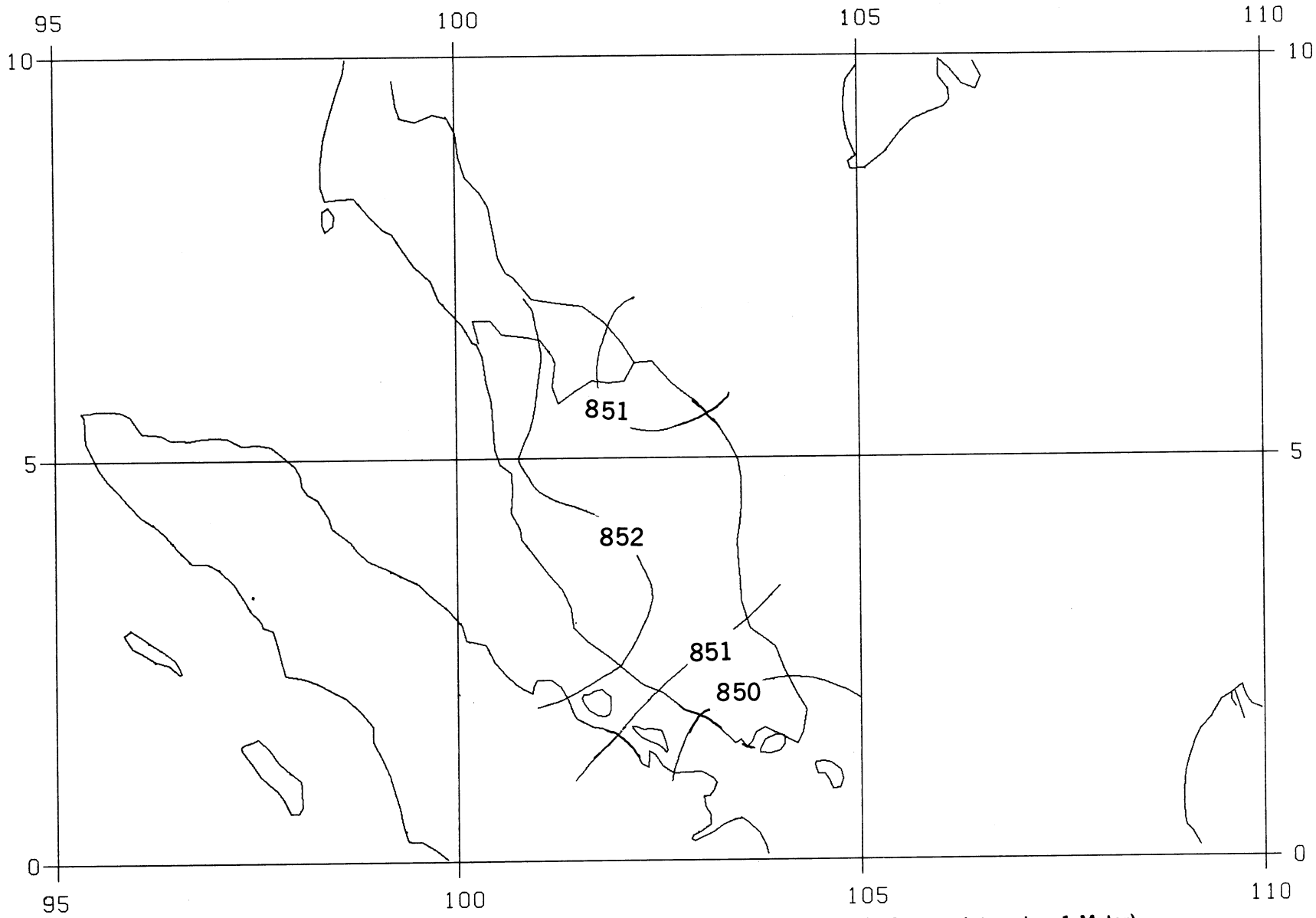

Figure 14.53. Contour Chart - Kertau Datum 1948 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

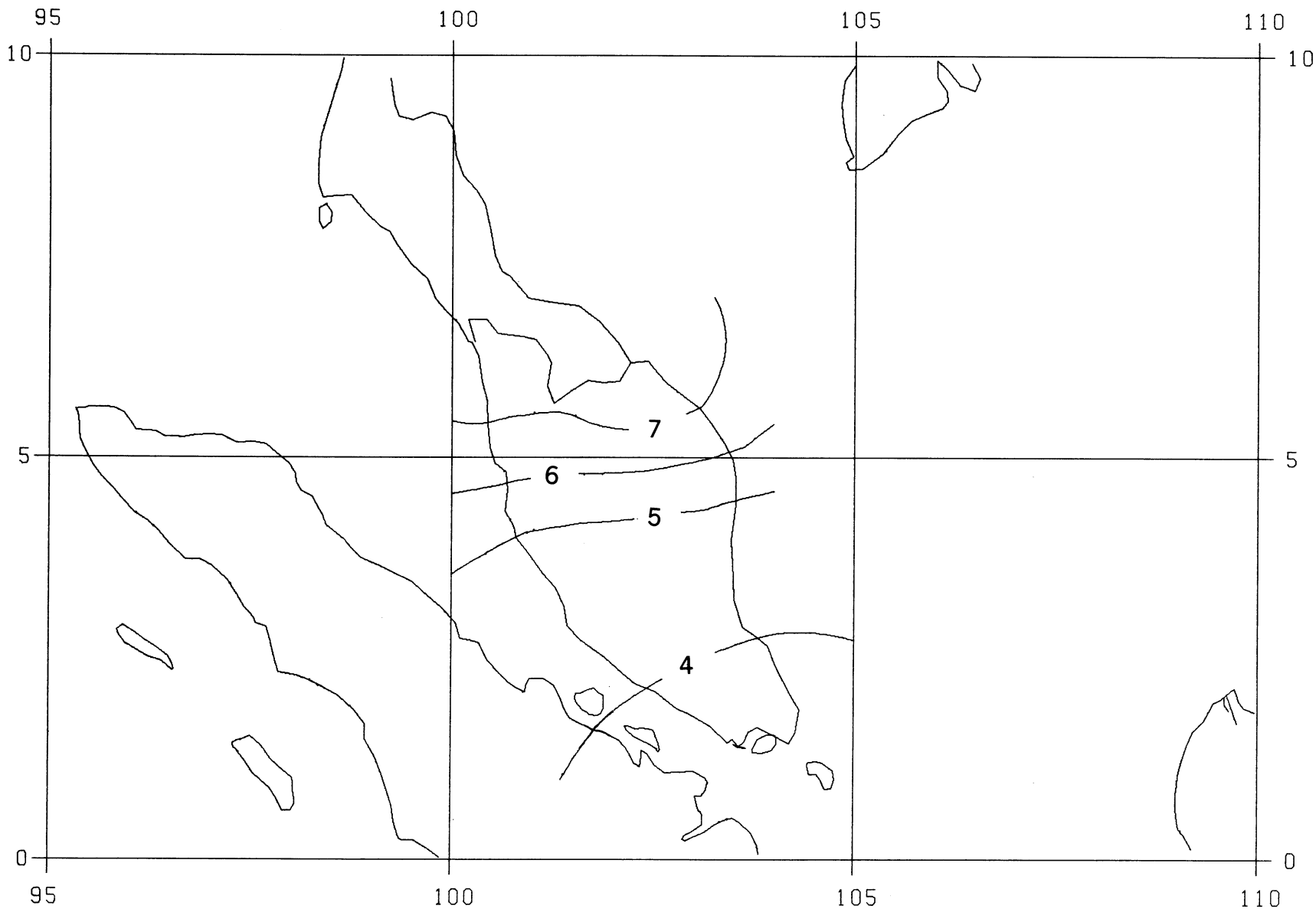

Figure 14.54. Contour Chart - Kertau Datum 1948 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

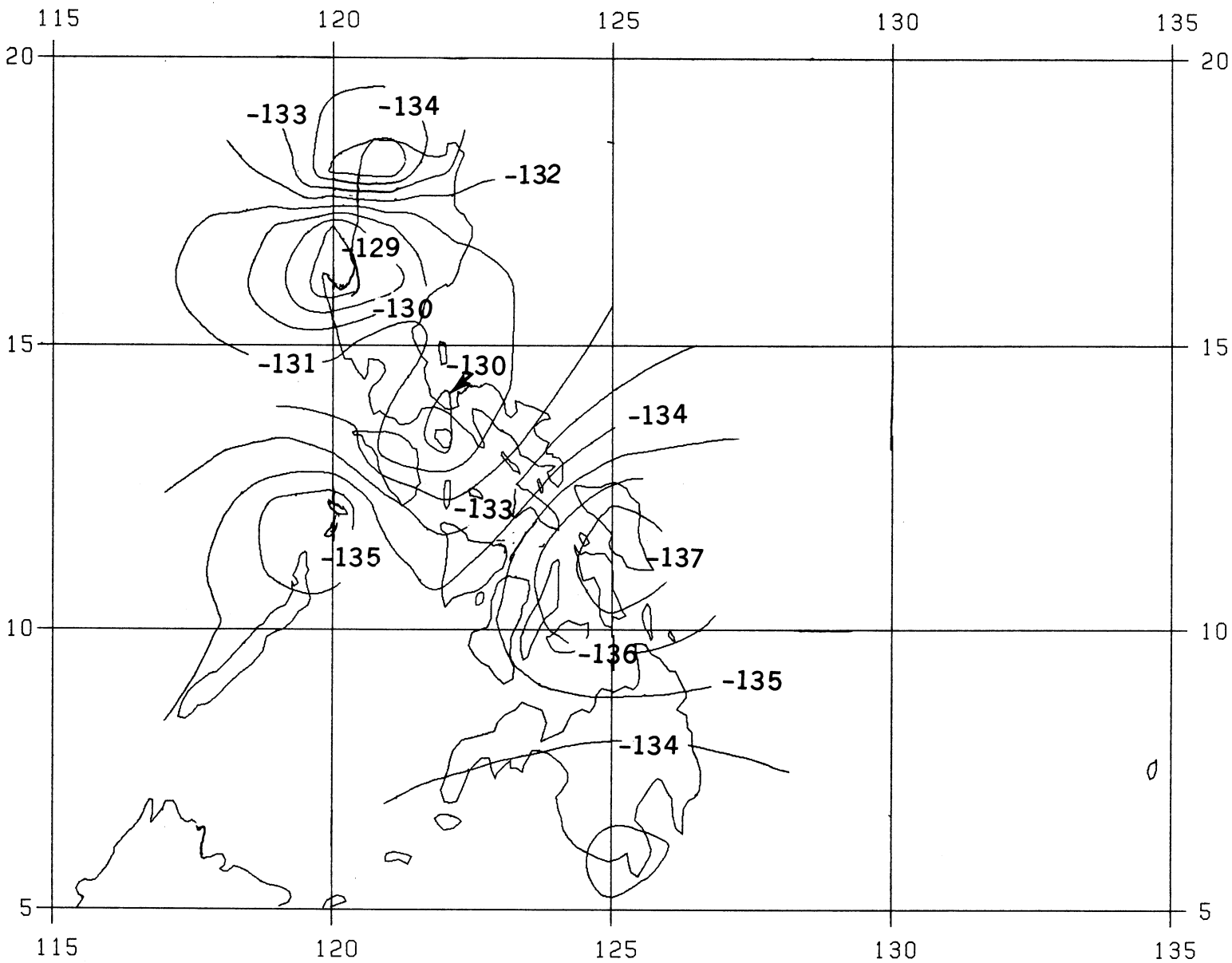

Figure 14.55. Contour Chart – Luzon Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

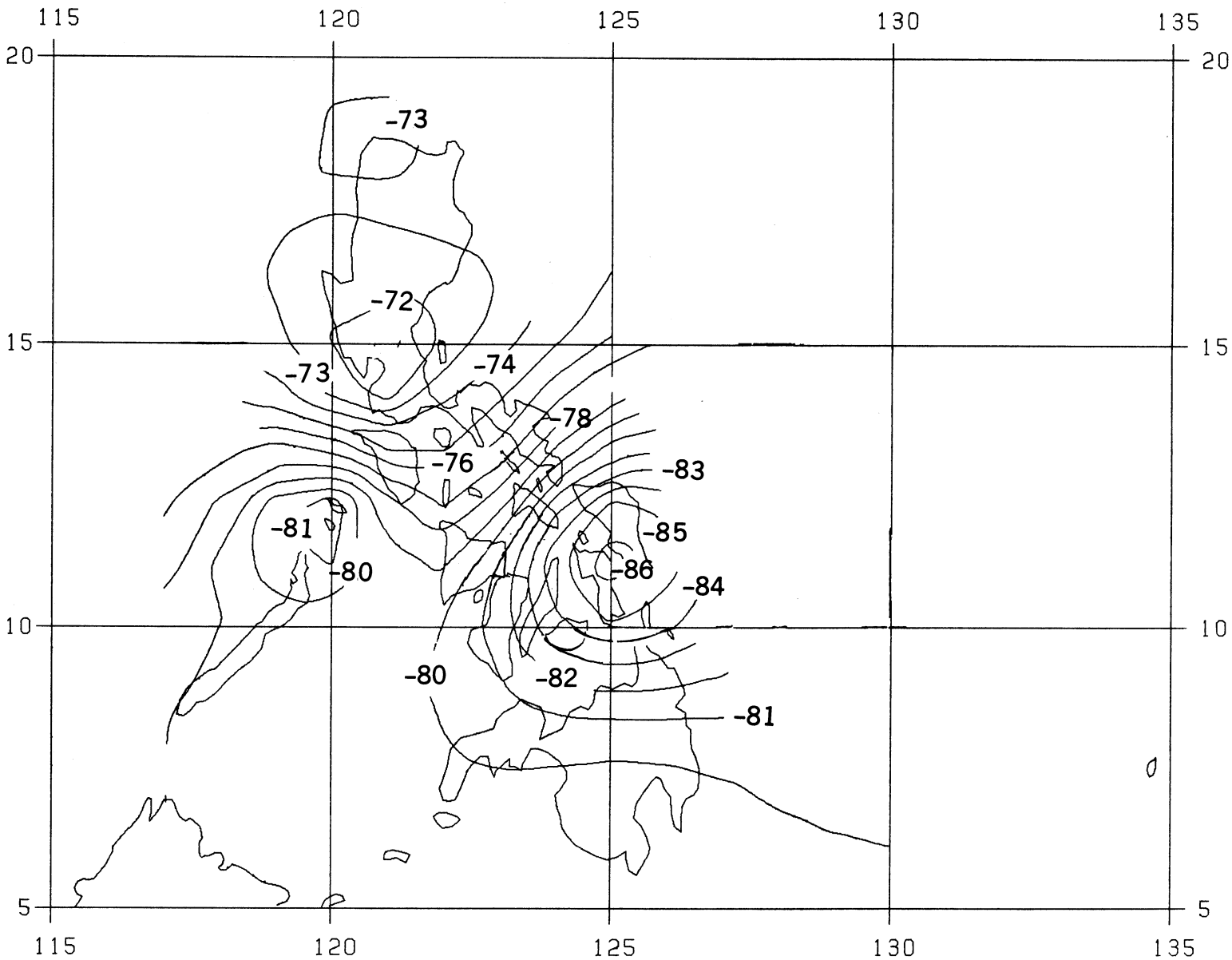

Figure 14.56. Contour Chart - Luzon Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

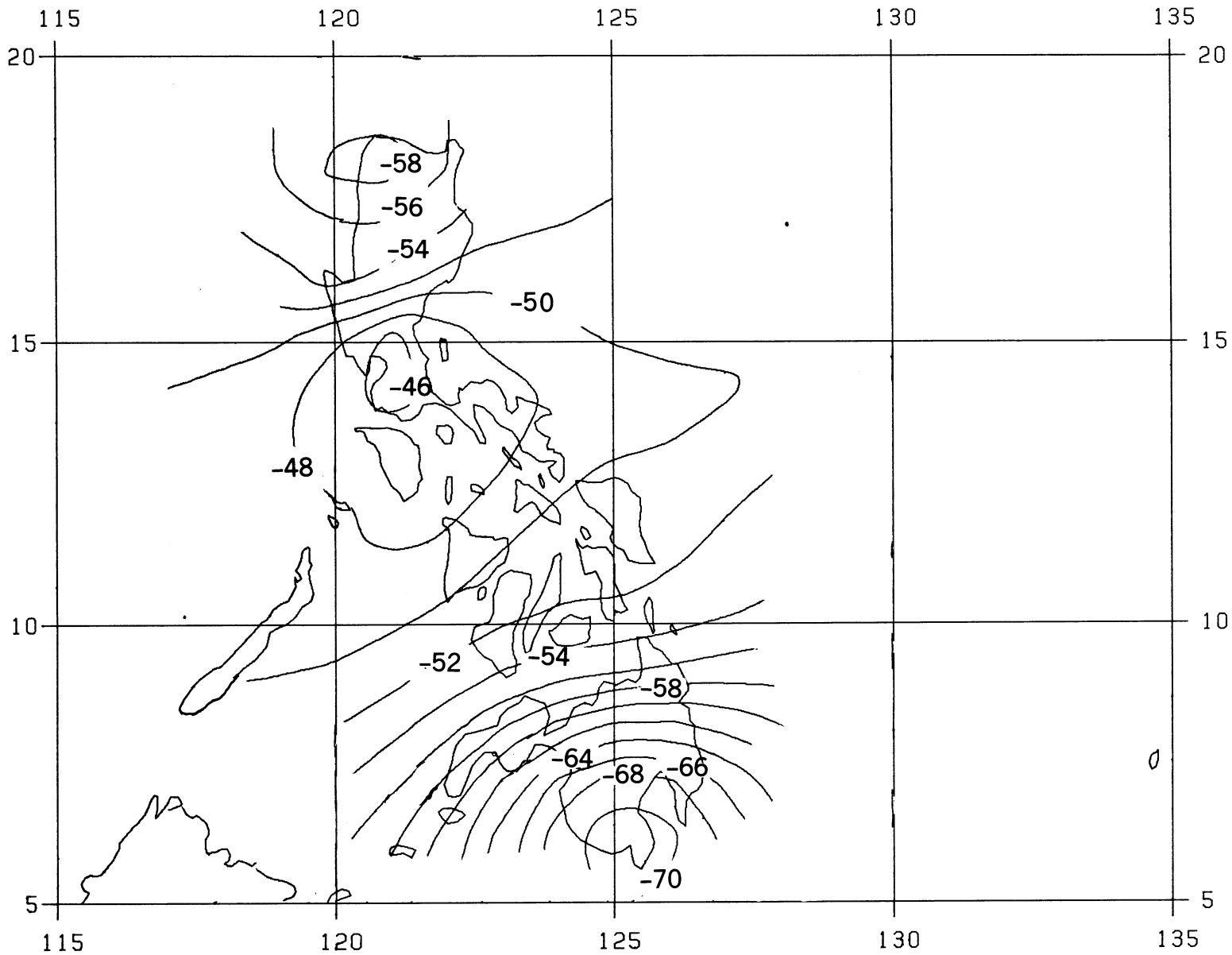

Figure 14.57. Contour Chart - Luzon Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 2 Meters)

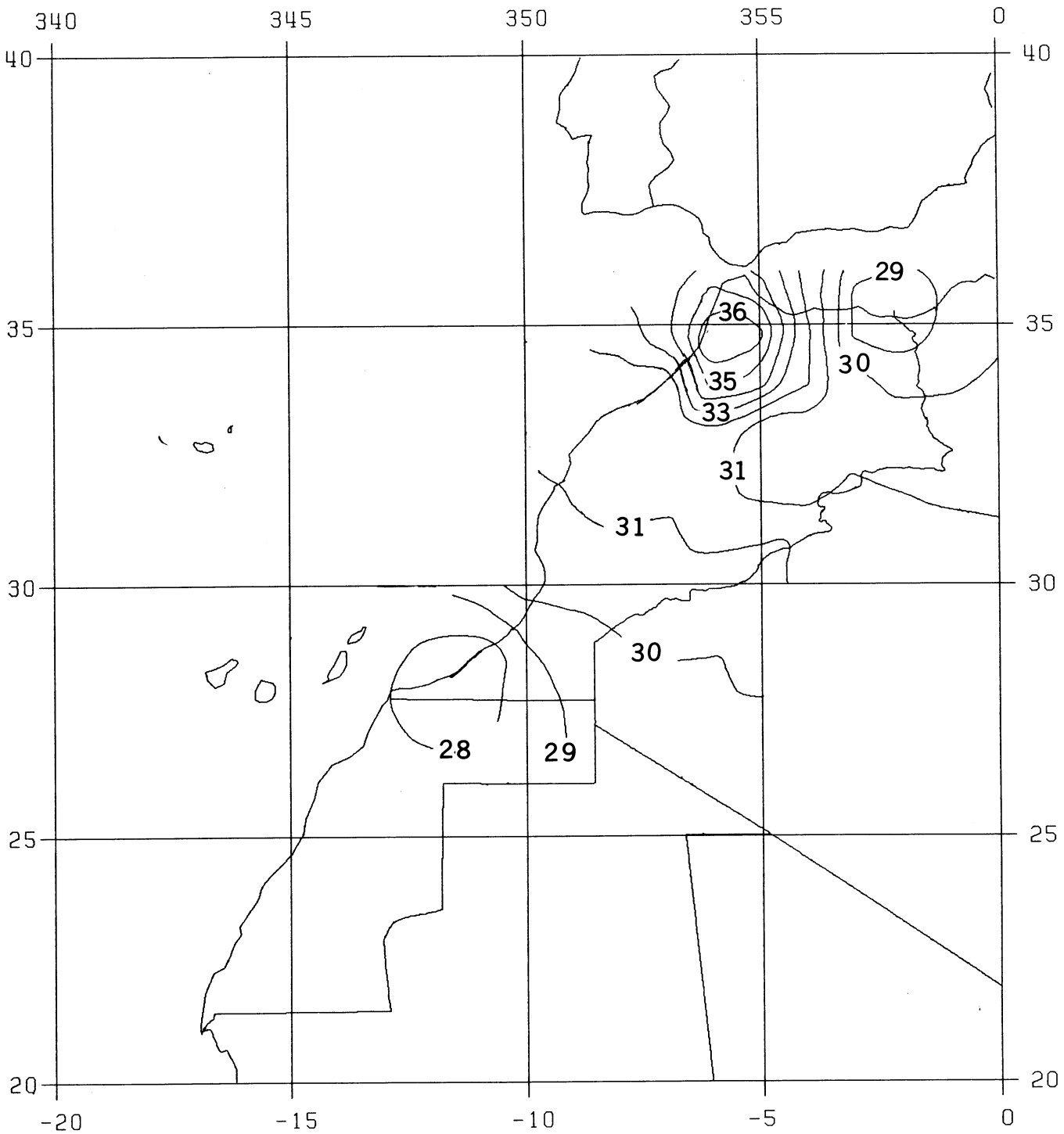

Figure 14.58. Contour Chart – Merchich Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

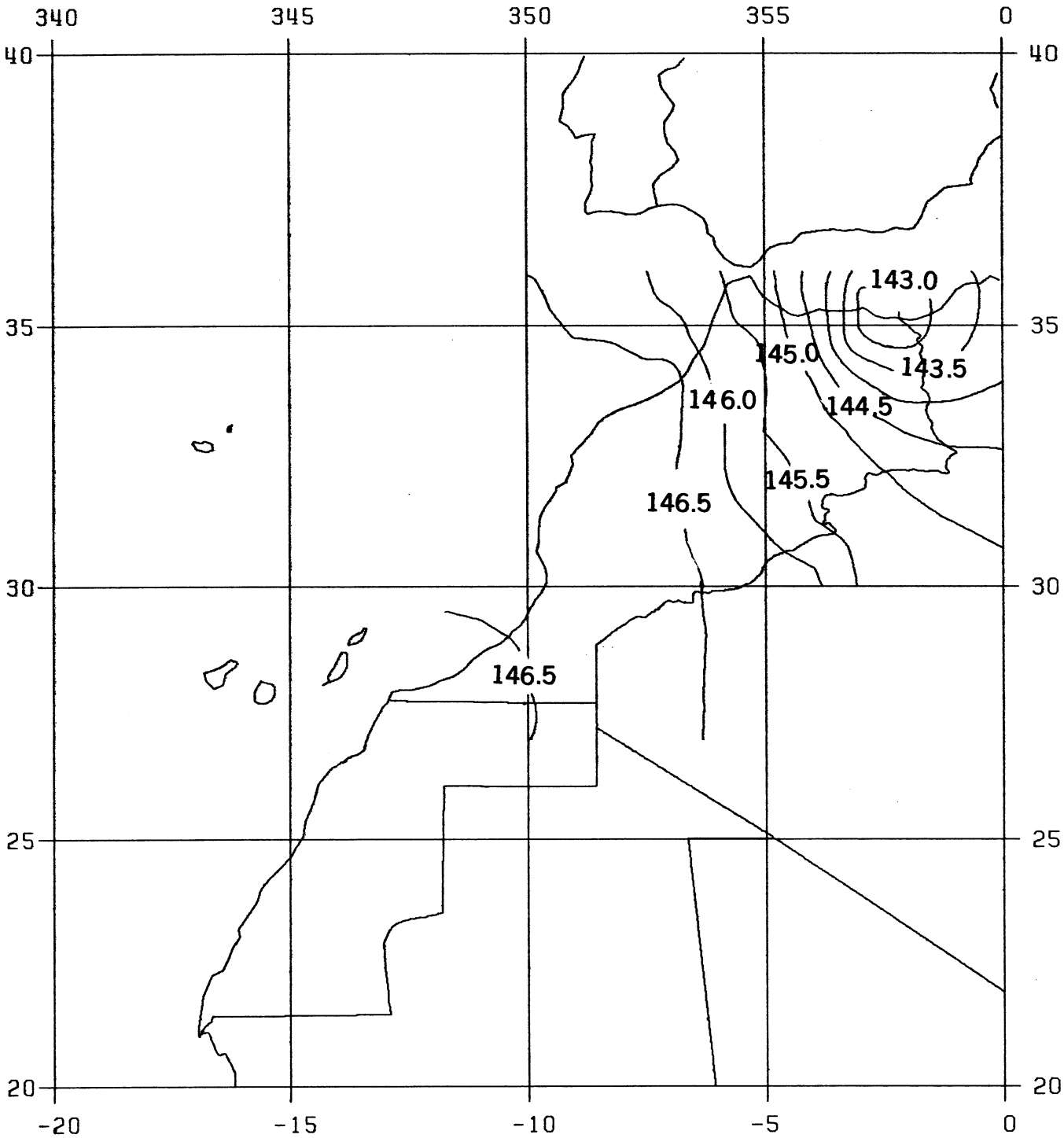

Figure 14.59. Contour Chart - Merchich Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 0.5 Meter)

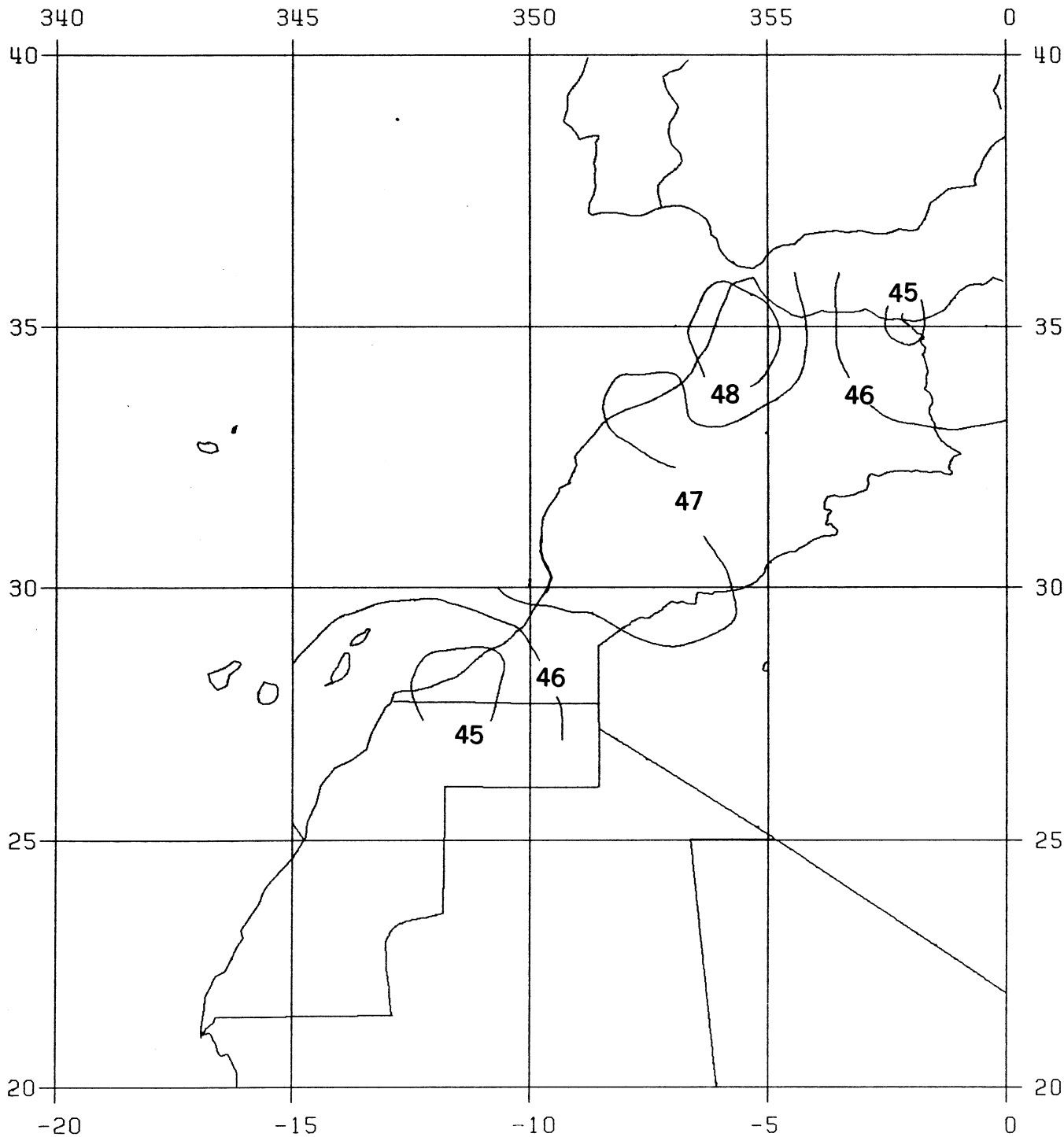

Figure 14.60. Contour Chart - Merchich Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

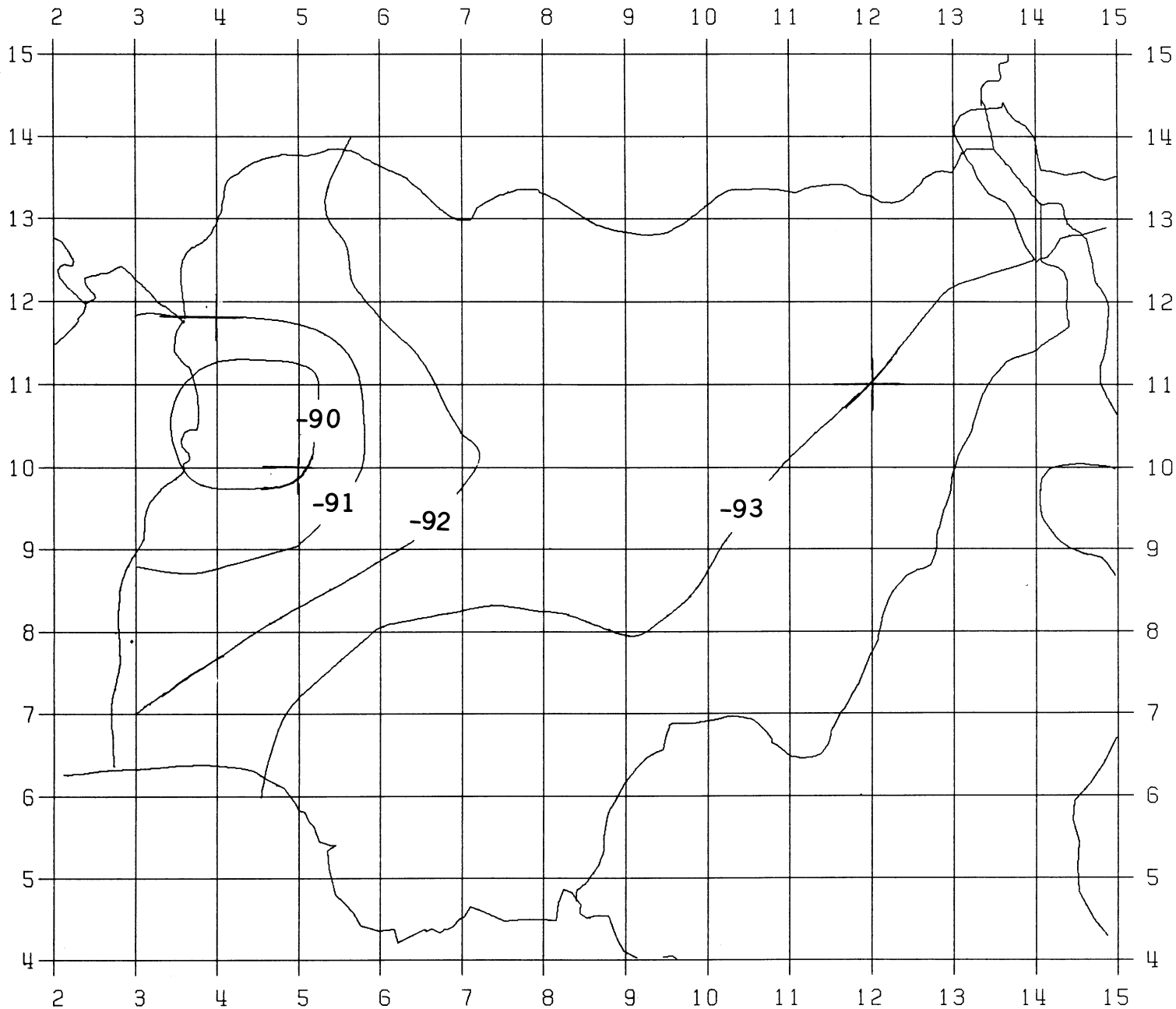

Figure 14.61. Contour Chart – Minna Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

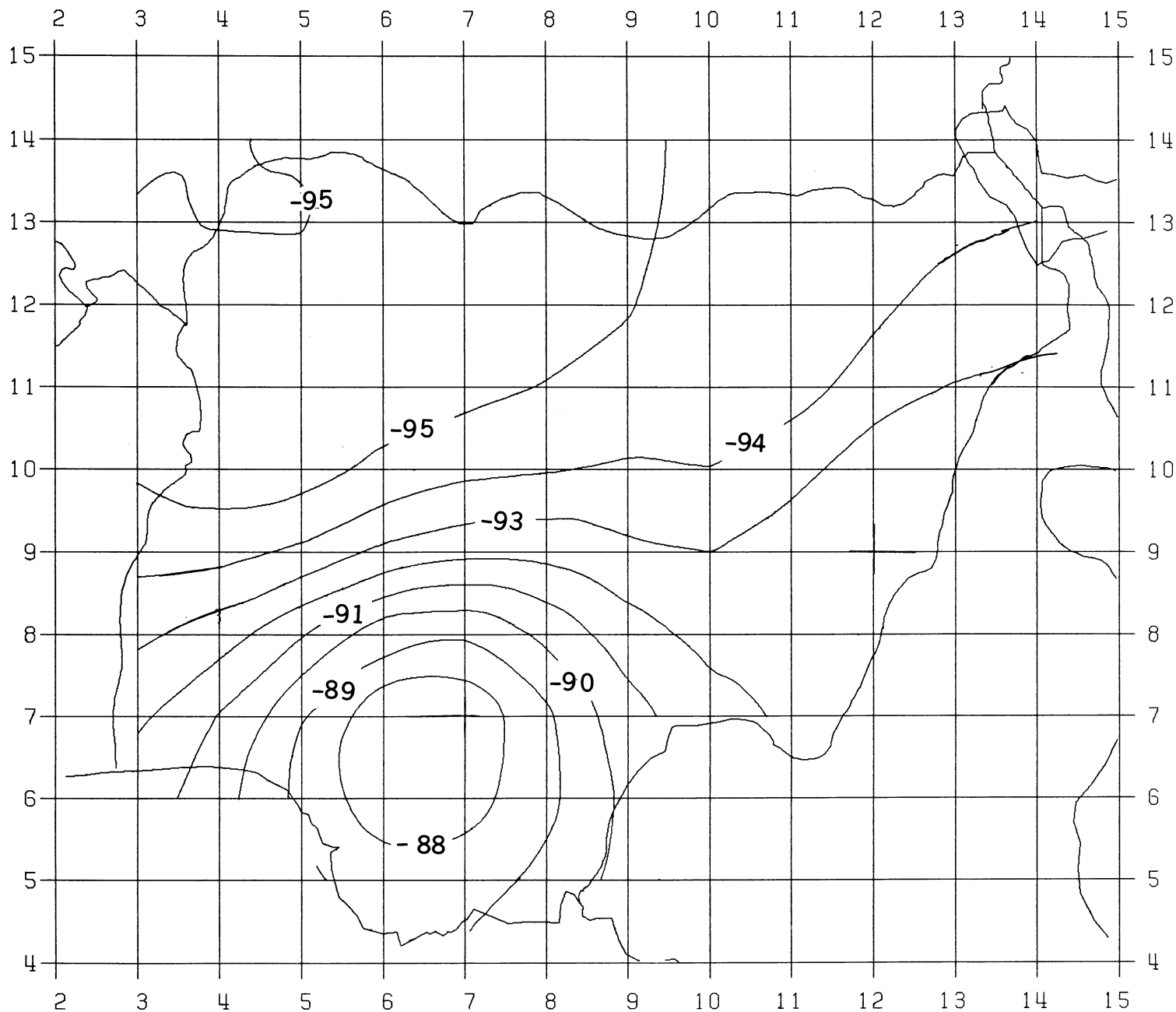

Figure 14.62. Contour Chart – Minna Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

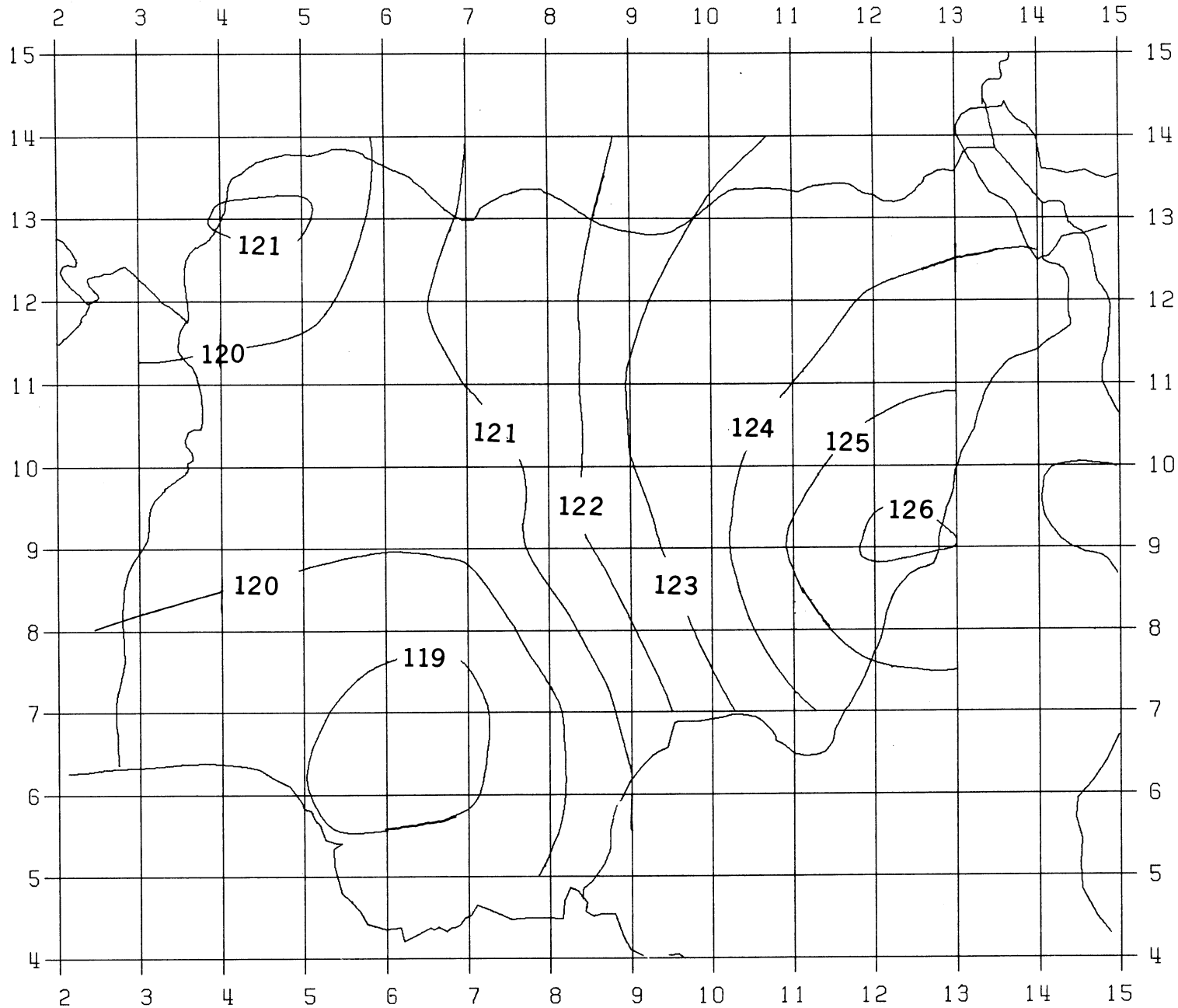

Figure 14.63. Contour Chart – Minna Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

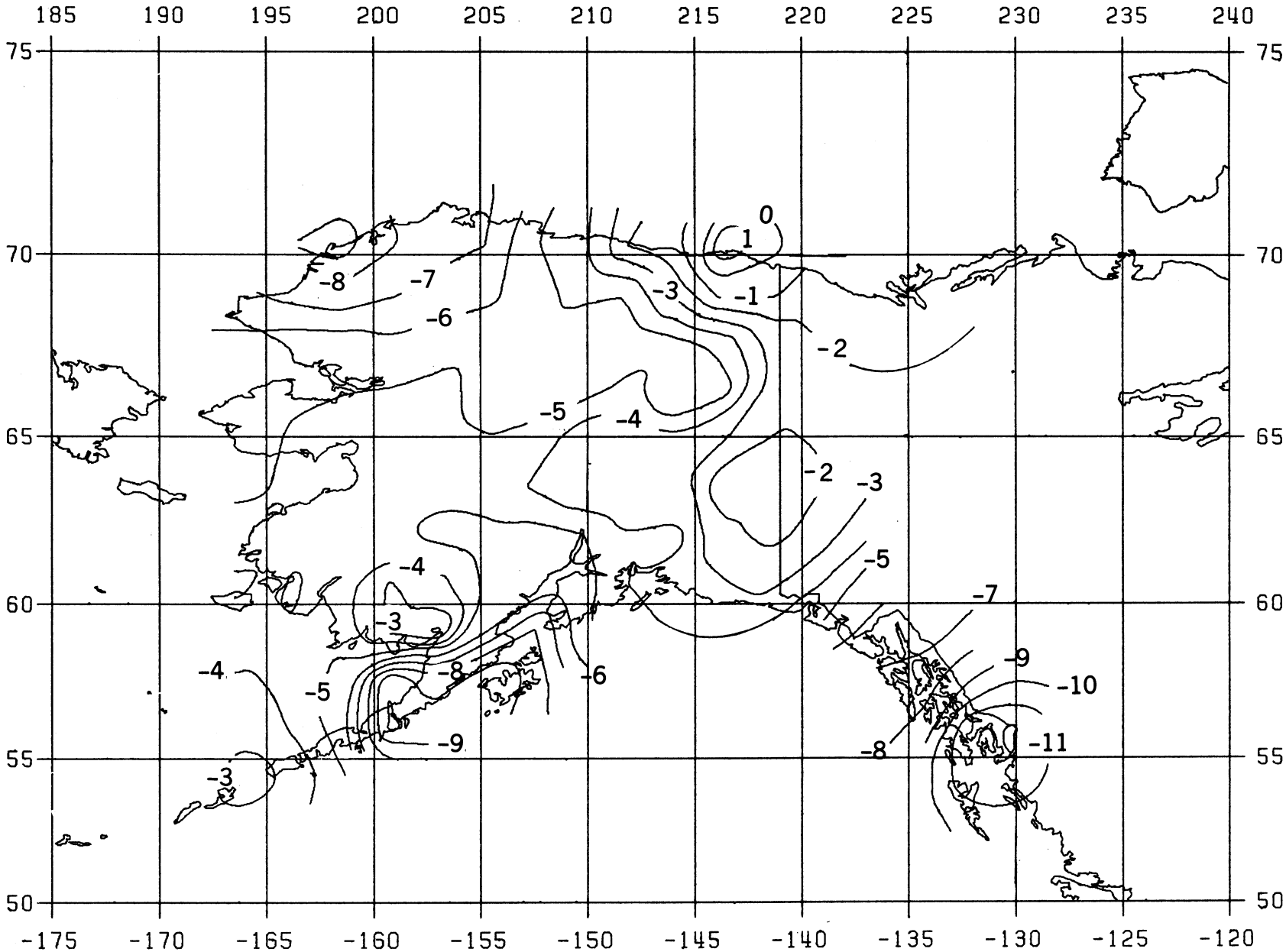

Figure 14.64. Contour Chart - NAD 27 (Alaska) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

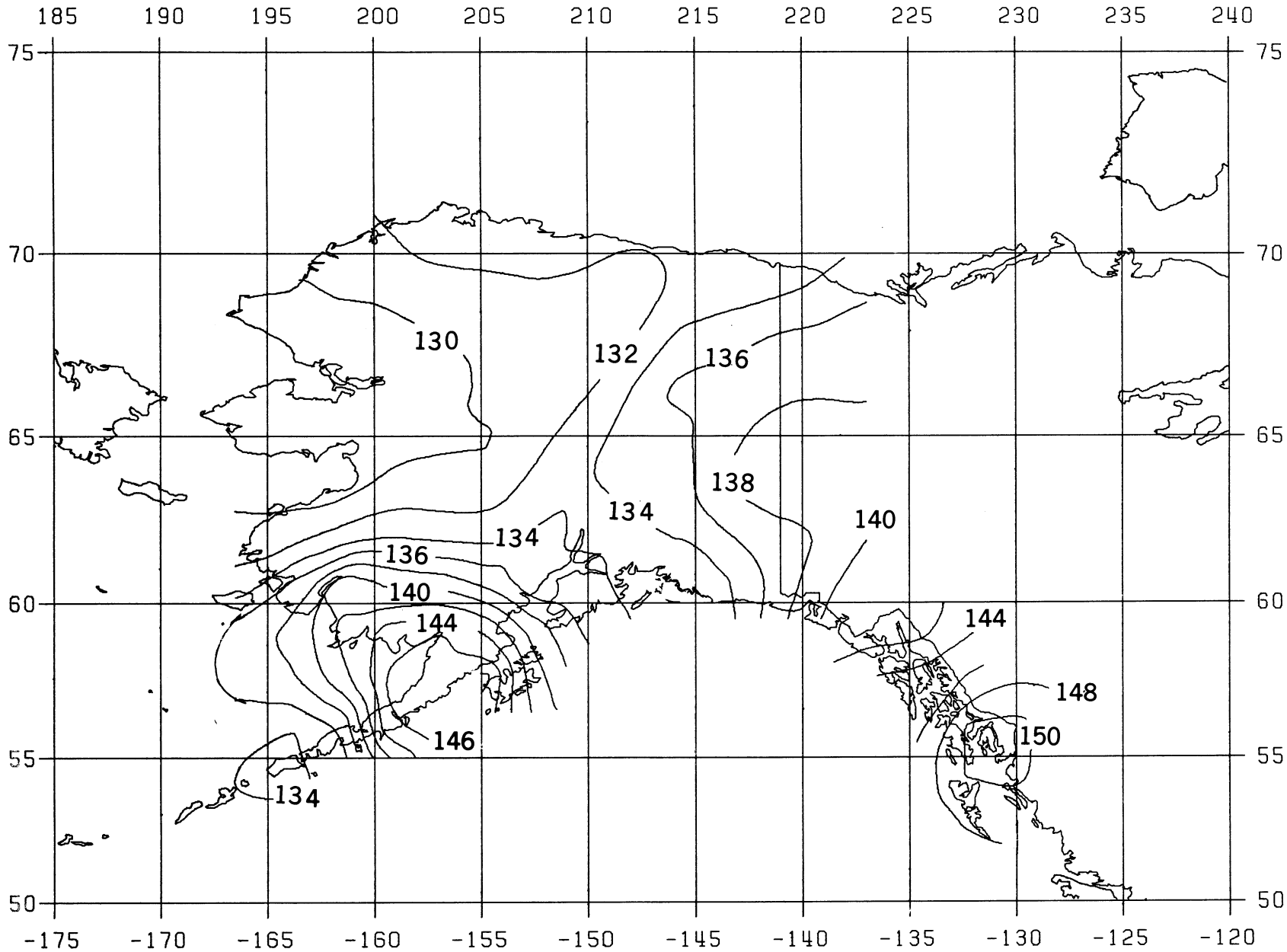

Figure 14.65. Contour Chart - NAD 27 (Alaska) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 2 Meters)

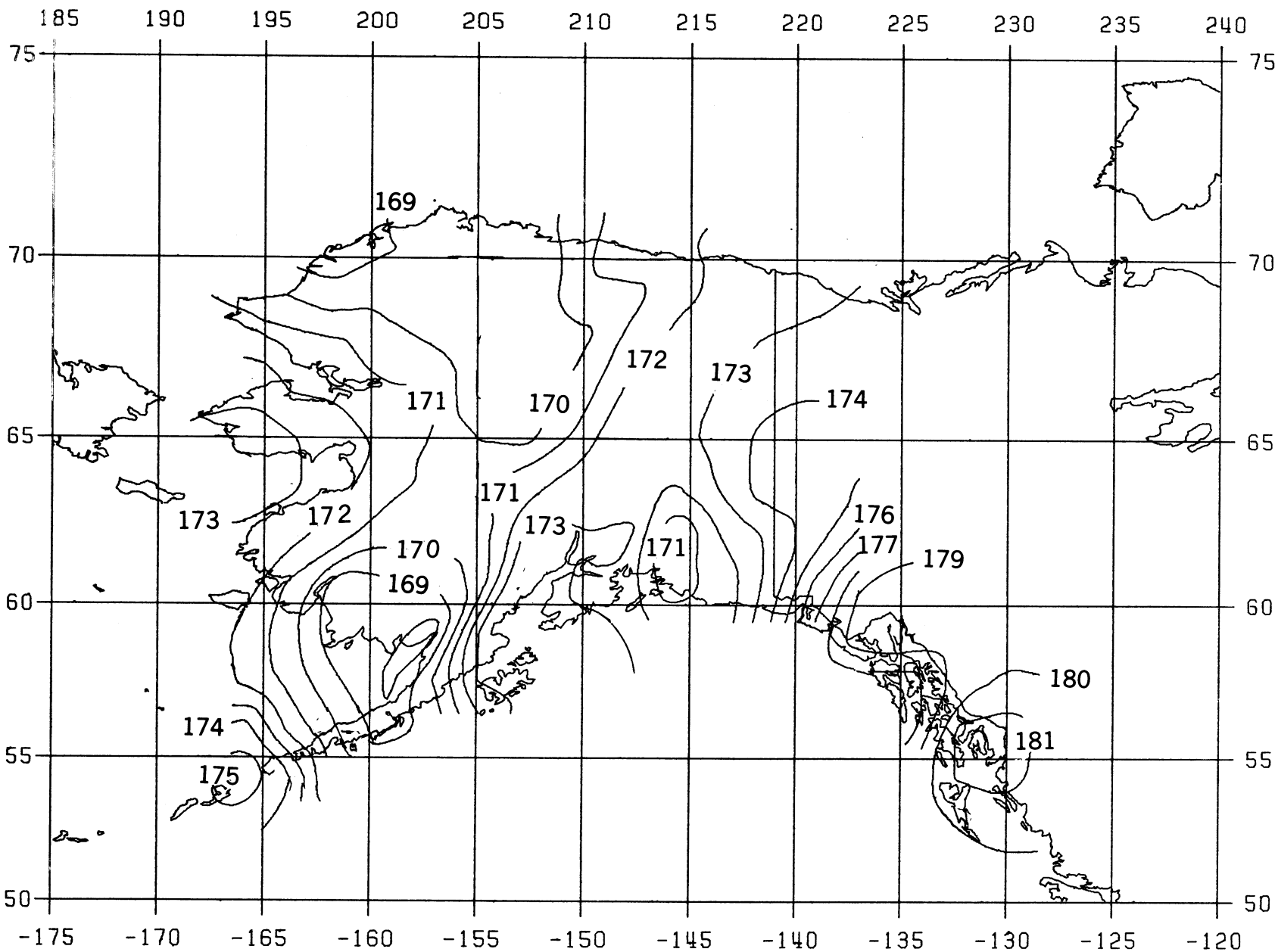

Figure 14.66. Contour Chart - NAD 27 (Alaska) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

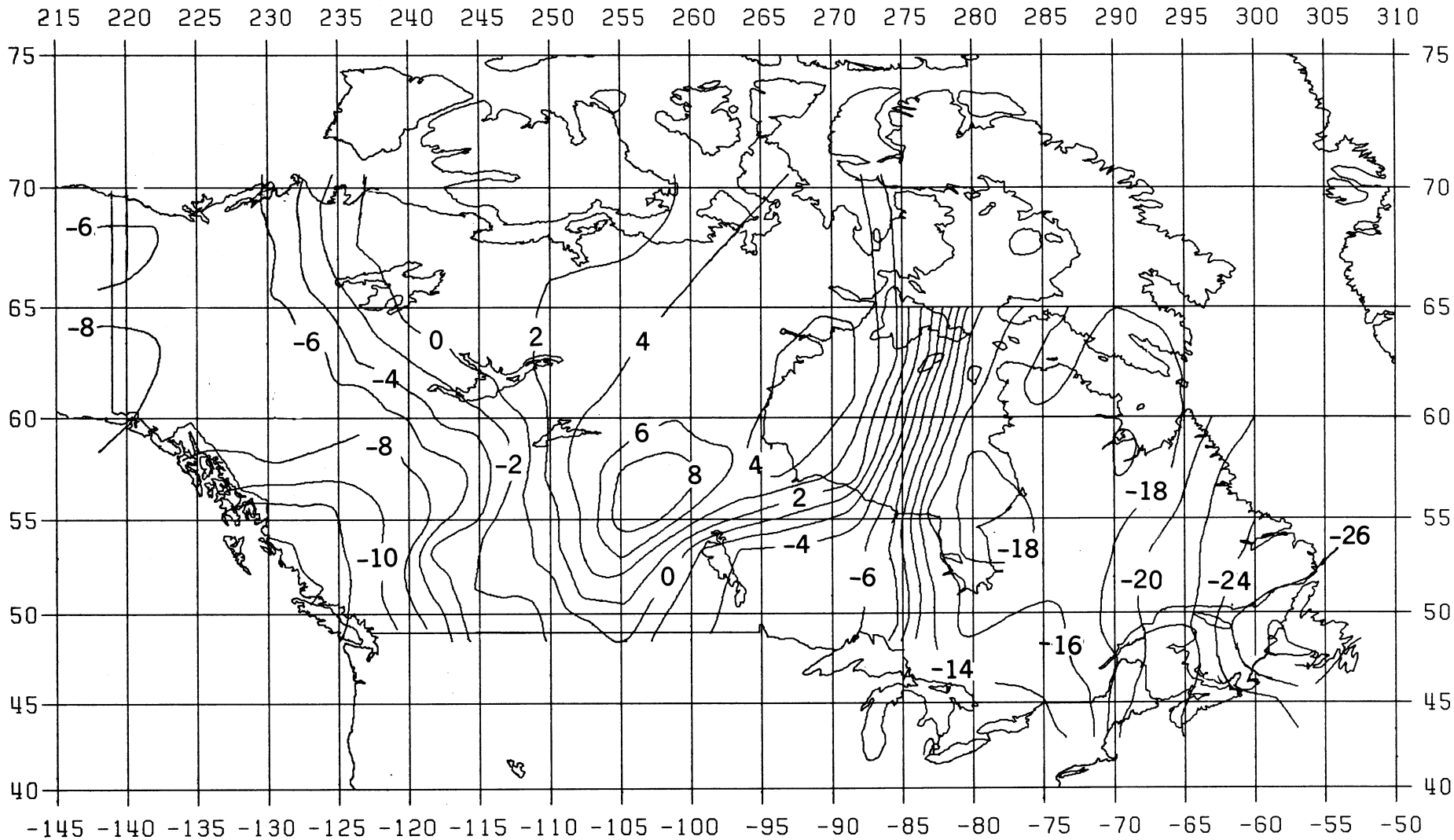

Figure 14.67. Contour Chart - NAD 27 (Canada) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 2 Meters)

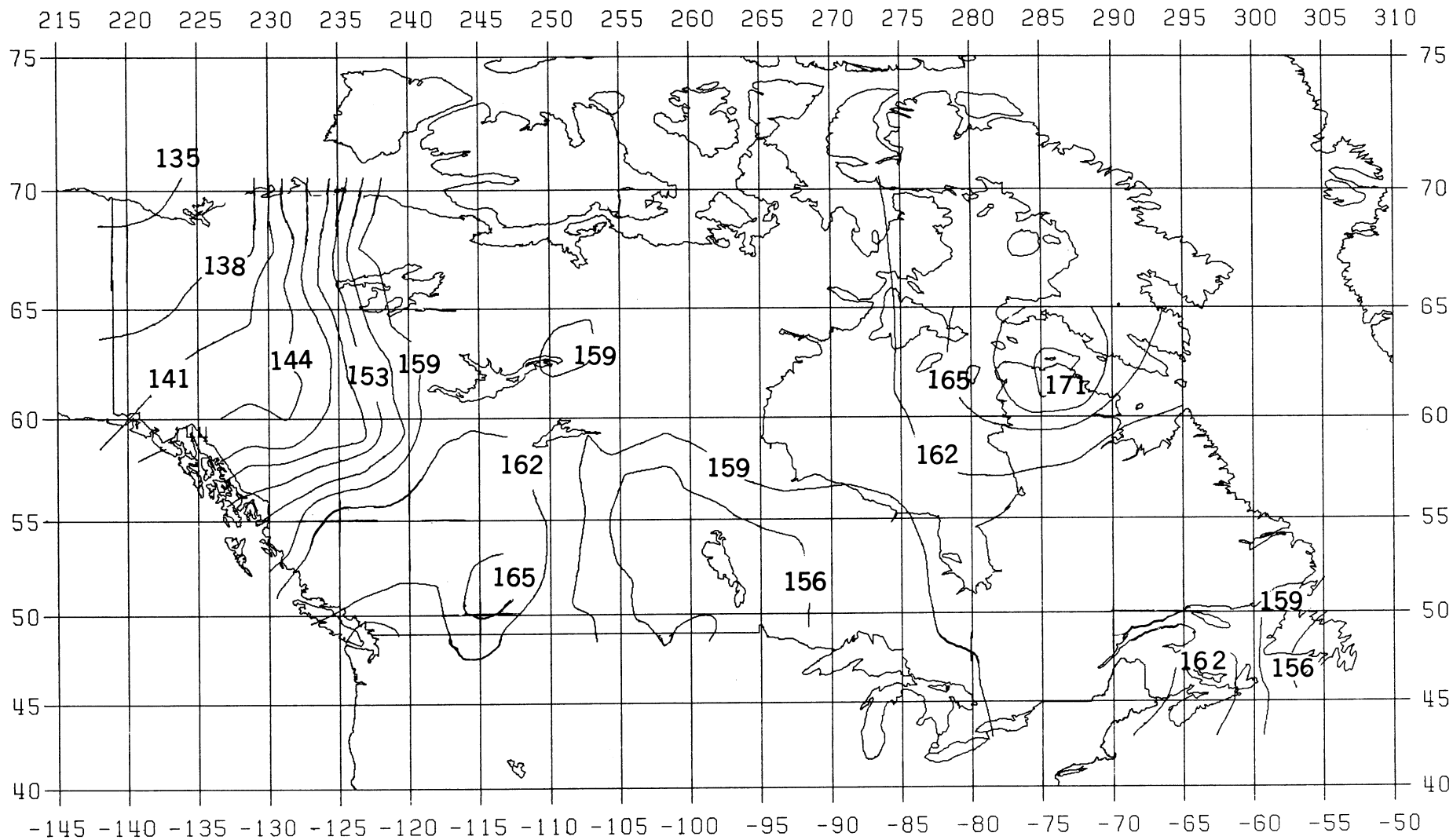

Figure 14.68. Contour Chart - NAD 27 (Canada) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 3 Meters)

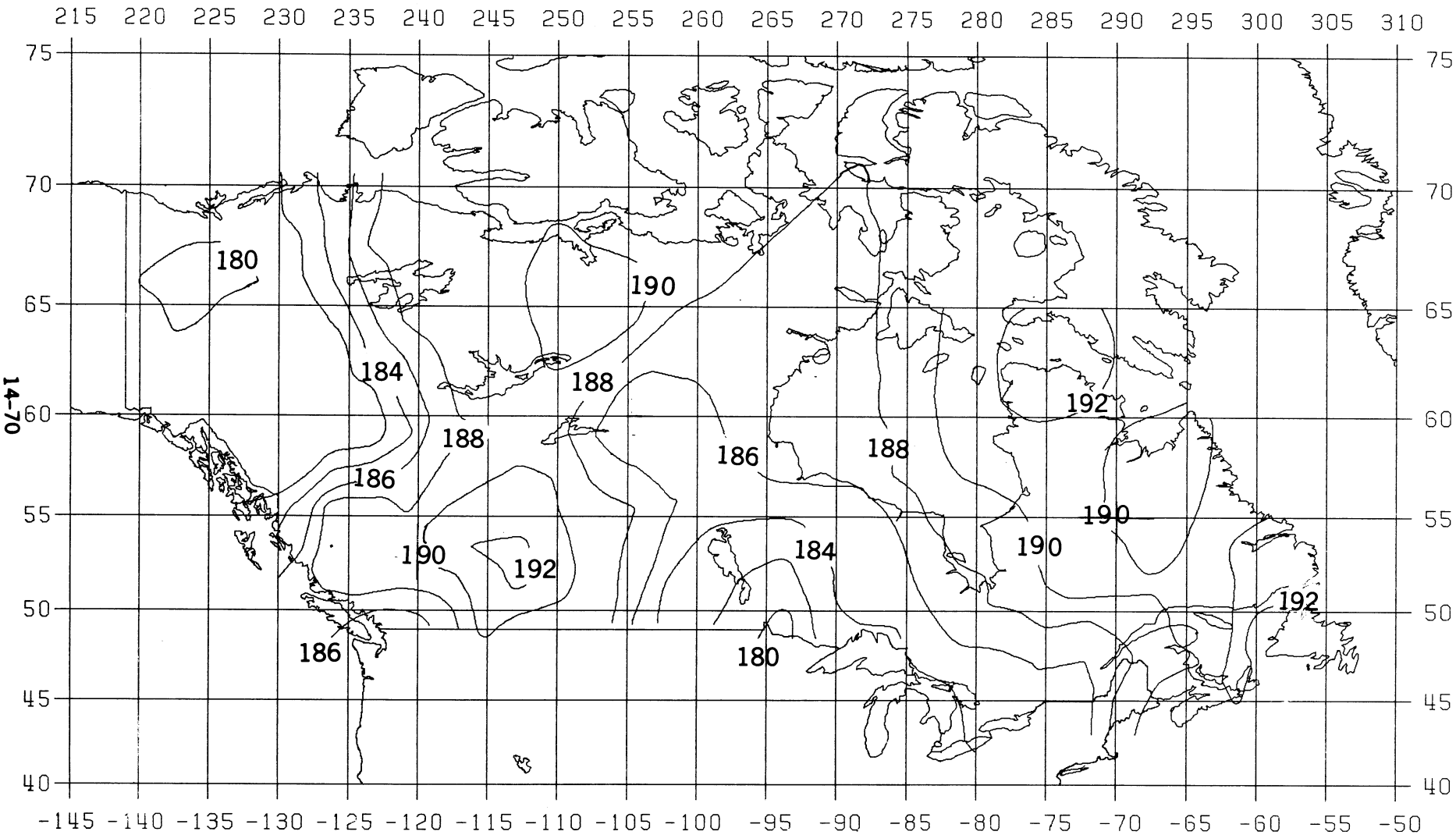

Figure 14.69. Contour Chart - NAD 27 (Canada) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 2 Meters)

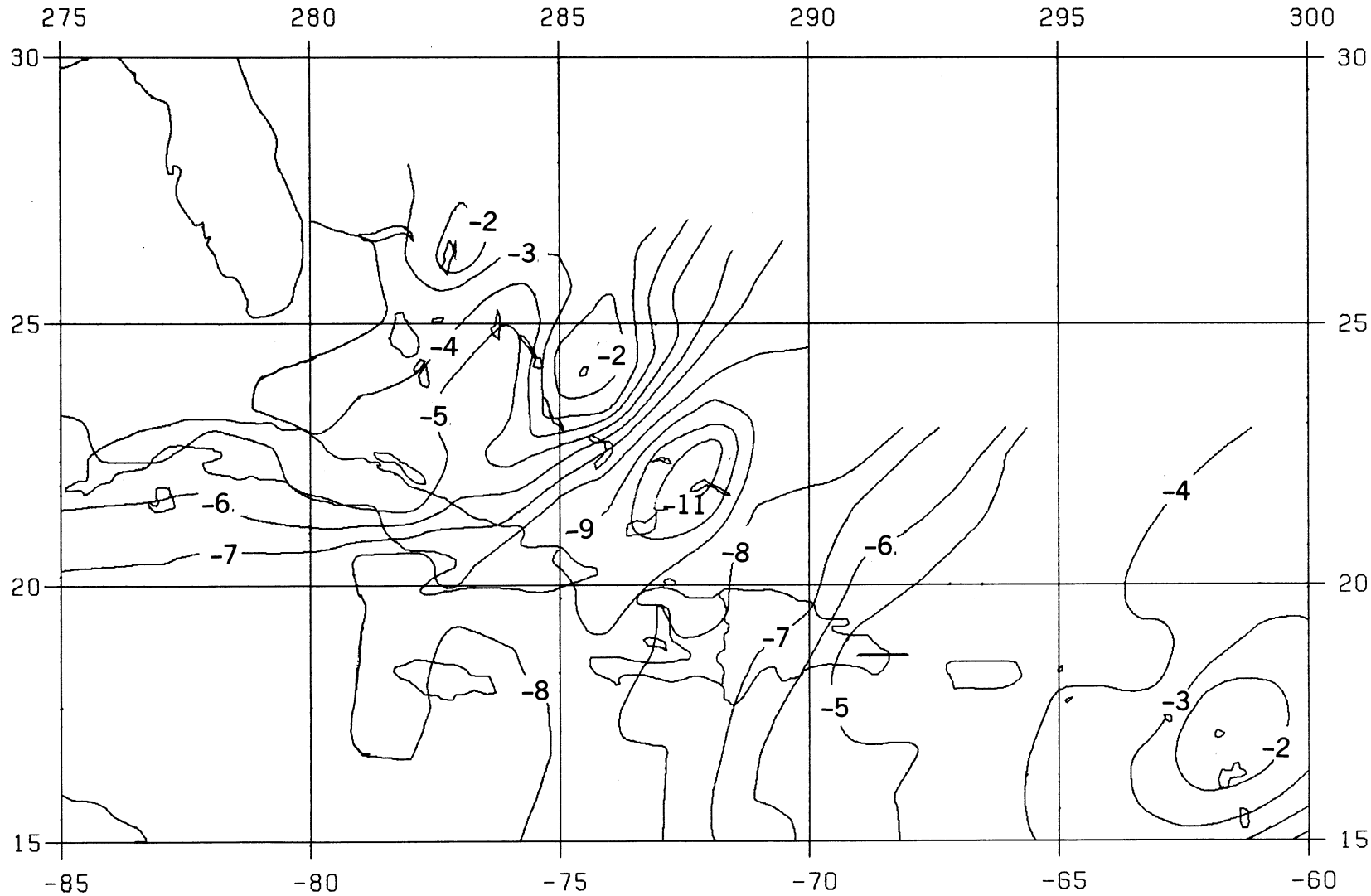

Figure 14.70. Contour Chart - NAD 27 (Caribbean) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

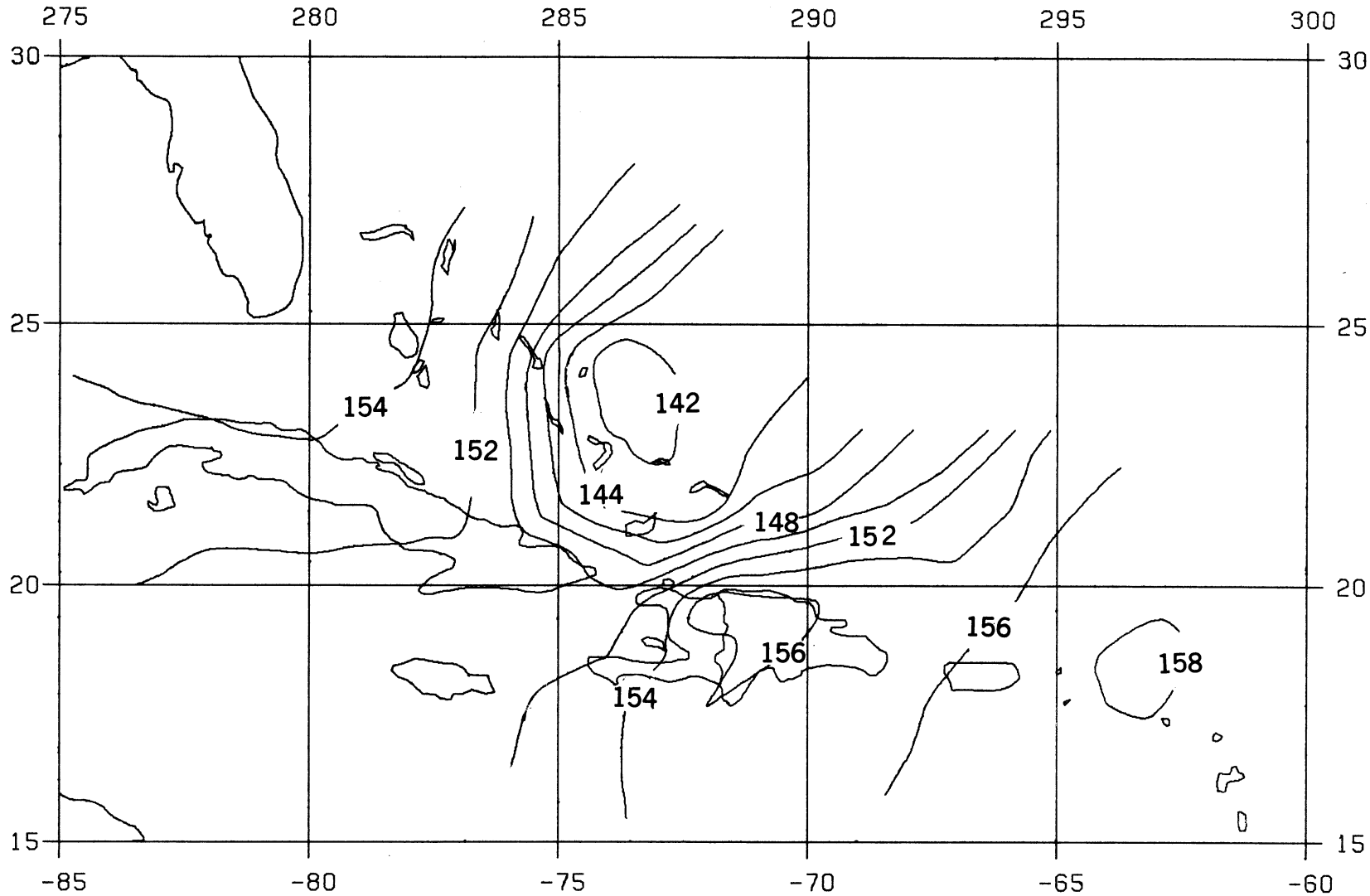

Figure 14.71. Contour Chart – NAD 27 (Caribbean) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 2 Meters)

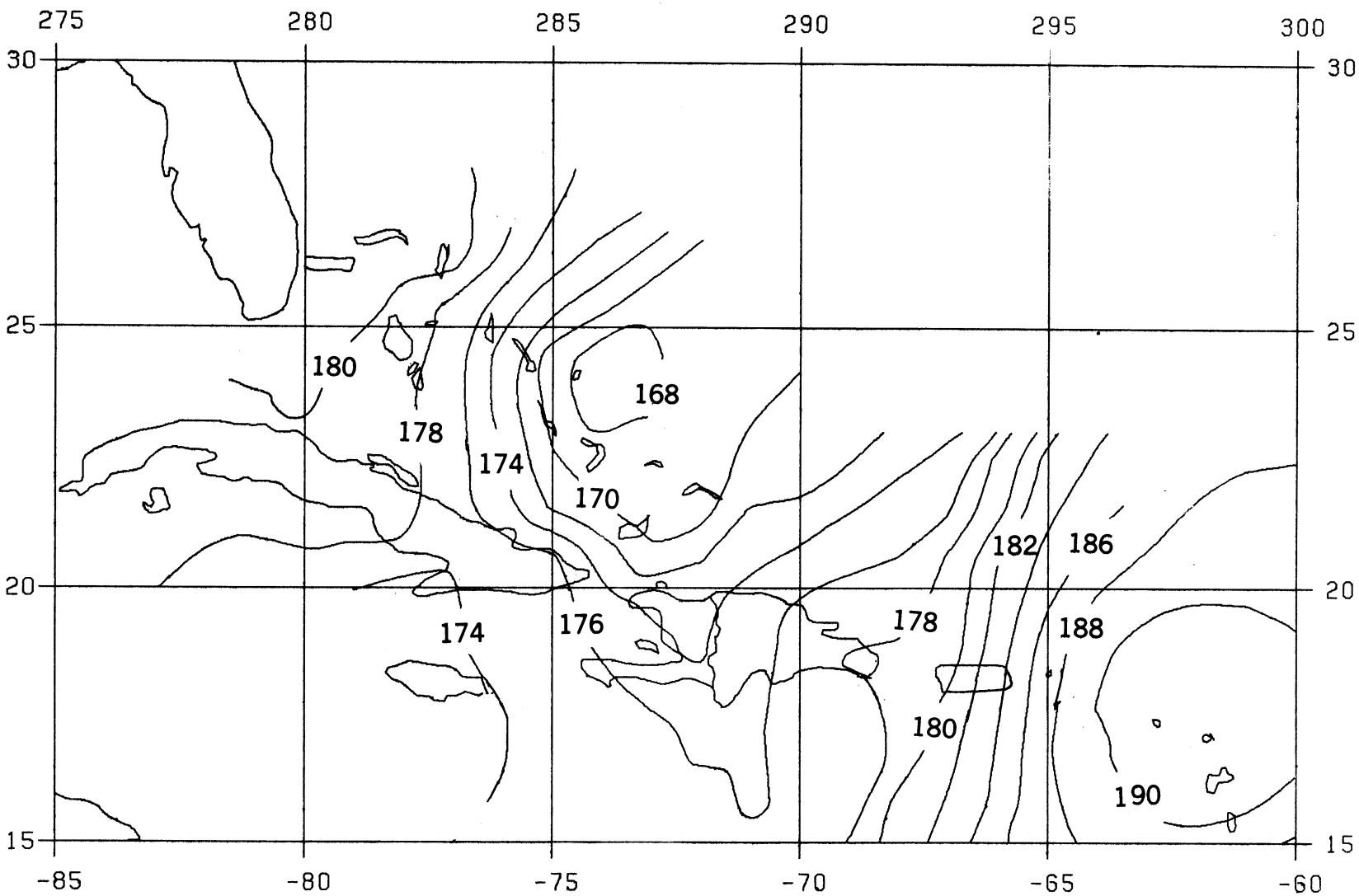

Figure 14.72. Contour Chart - NAD 27 (Caribbean) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 2 Meters)

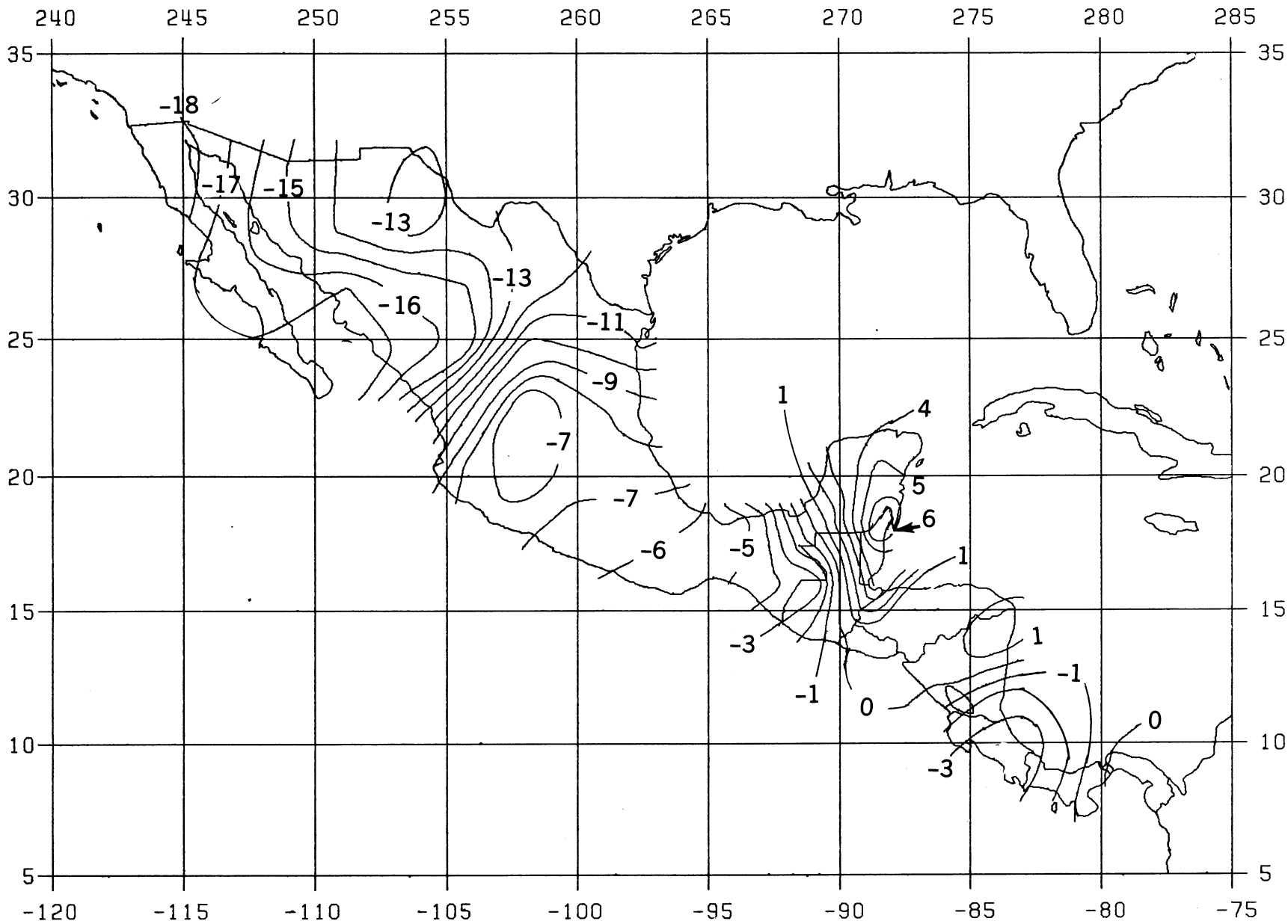

Figure 14.73. Contour Chart-NAD 27 (Mexico, Central America) to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

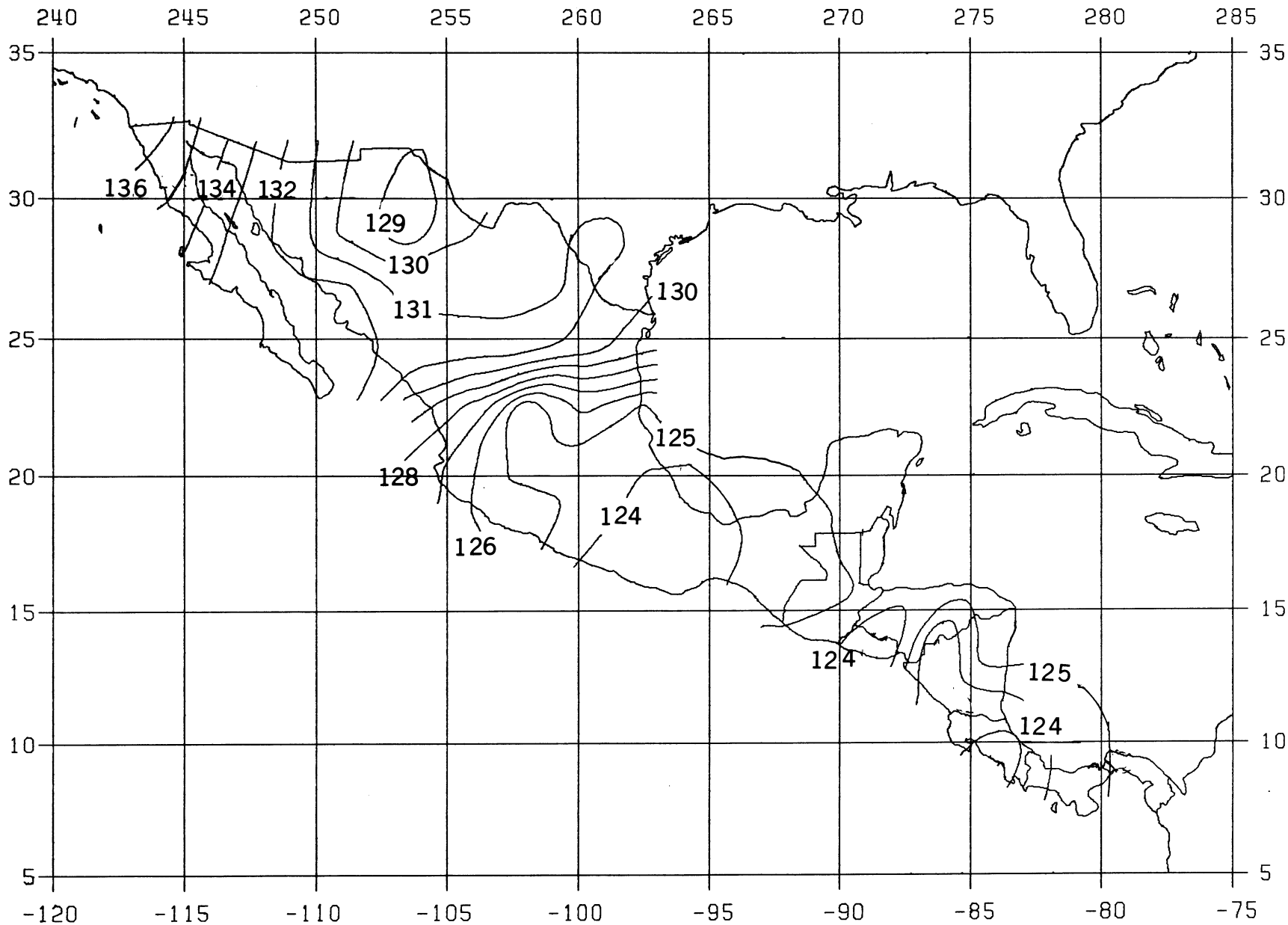

Figure 14.74. Contour Chart - NAD 27 (Mexico, Central America) to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

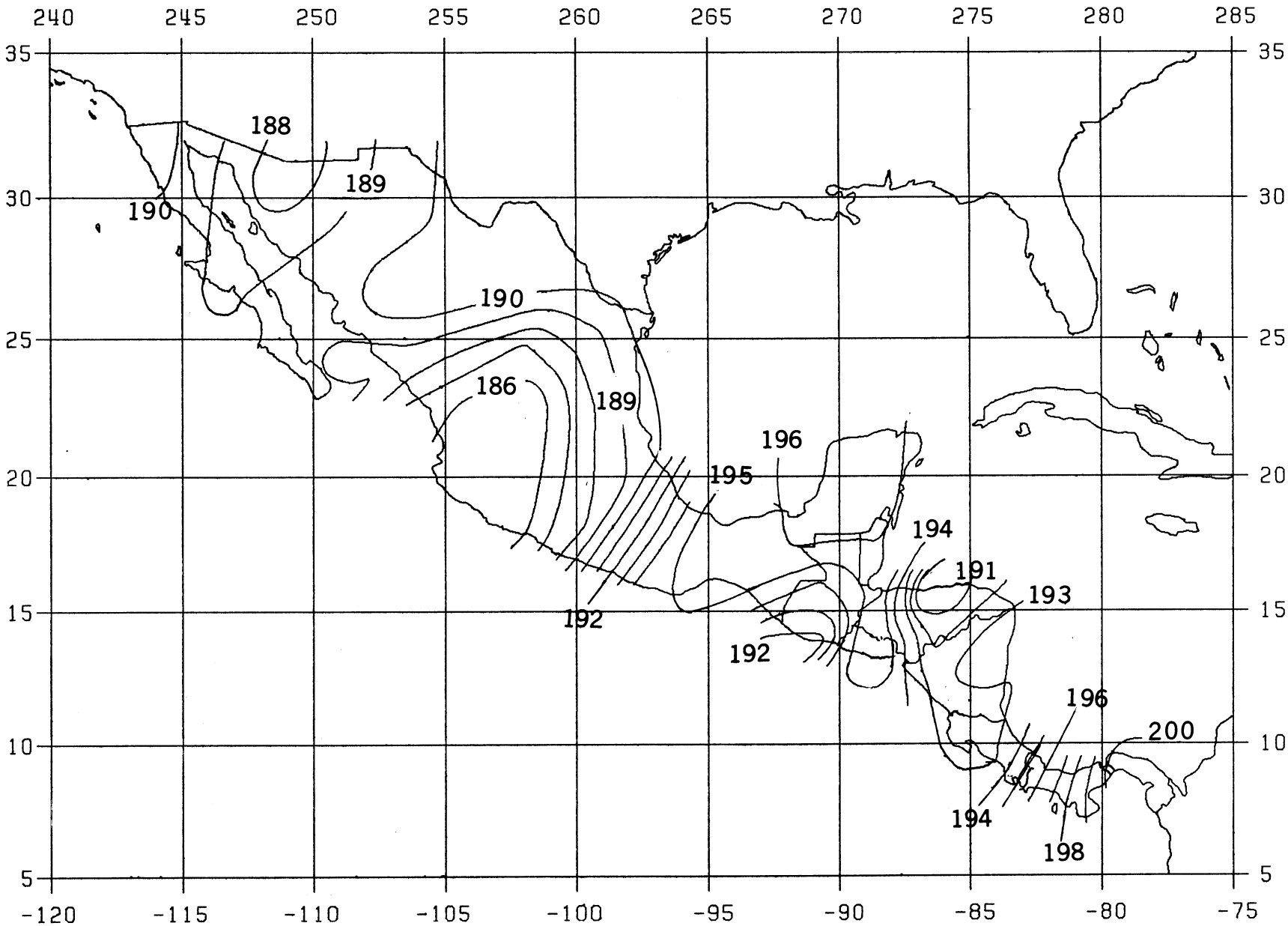

Figure 14.75. Contour Chart-NAD 27 (Mexico, Central America) to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

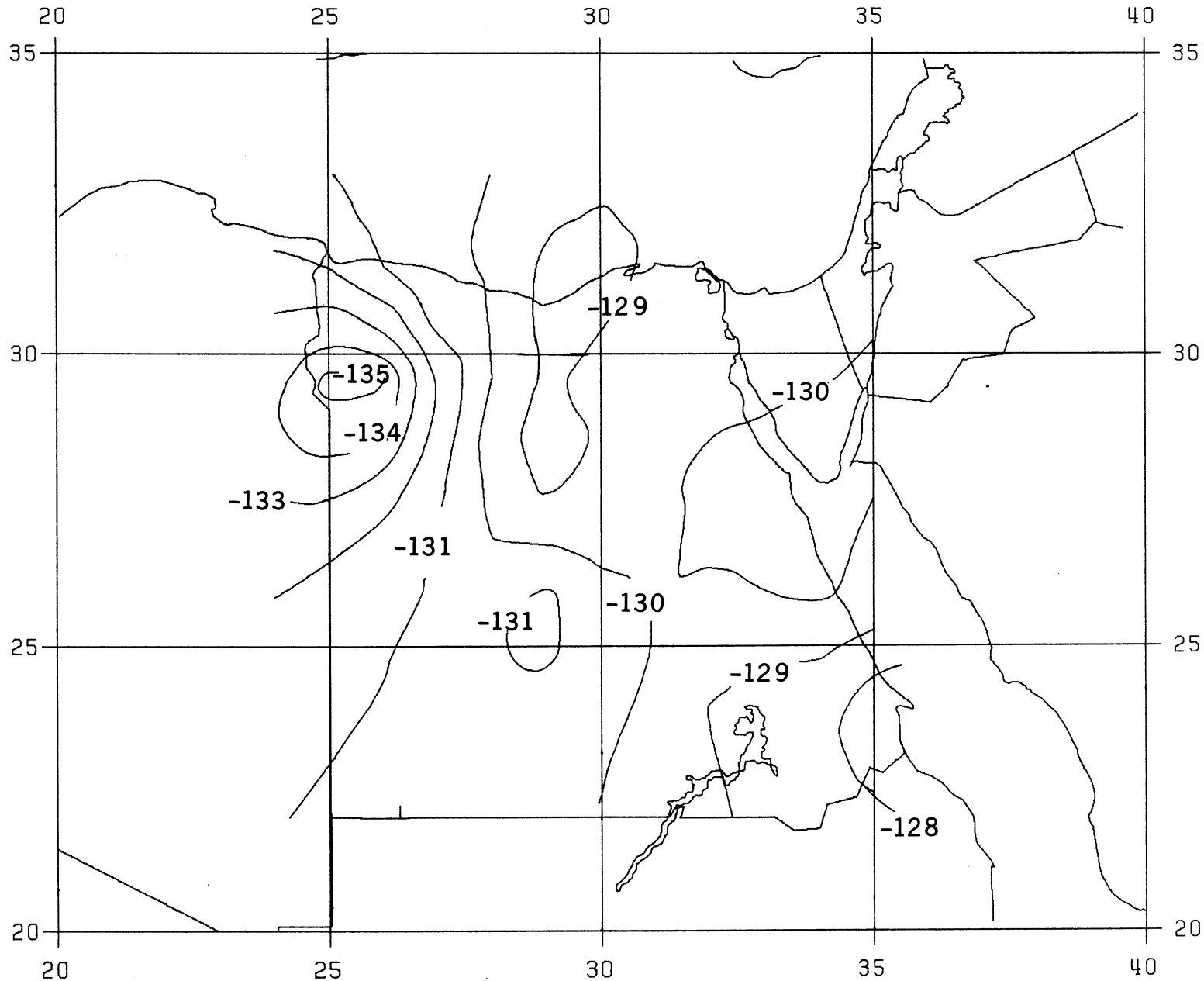

Figure 14.76. Contour Chart - Old Egyptian Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

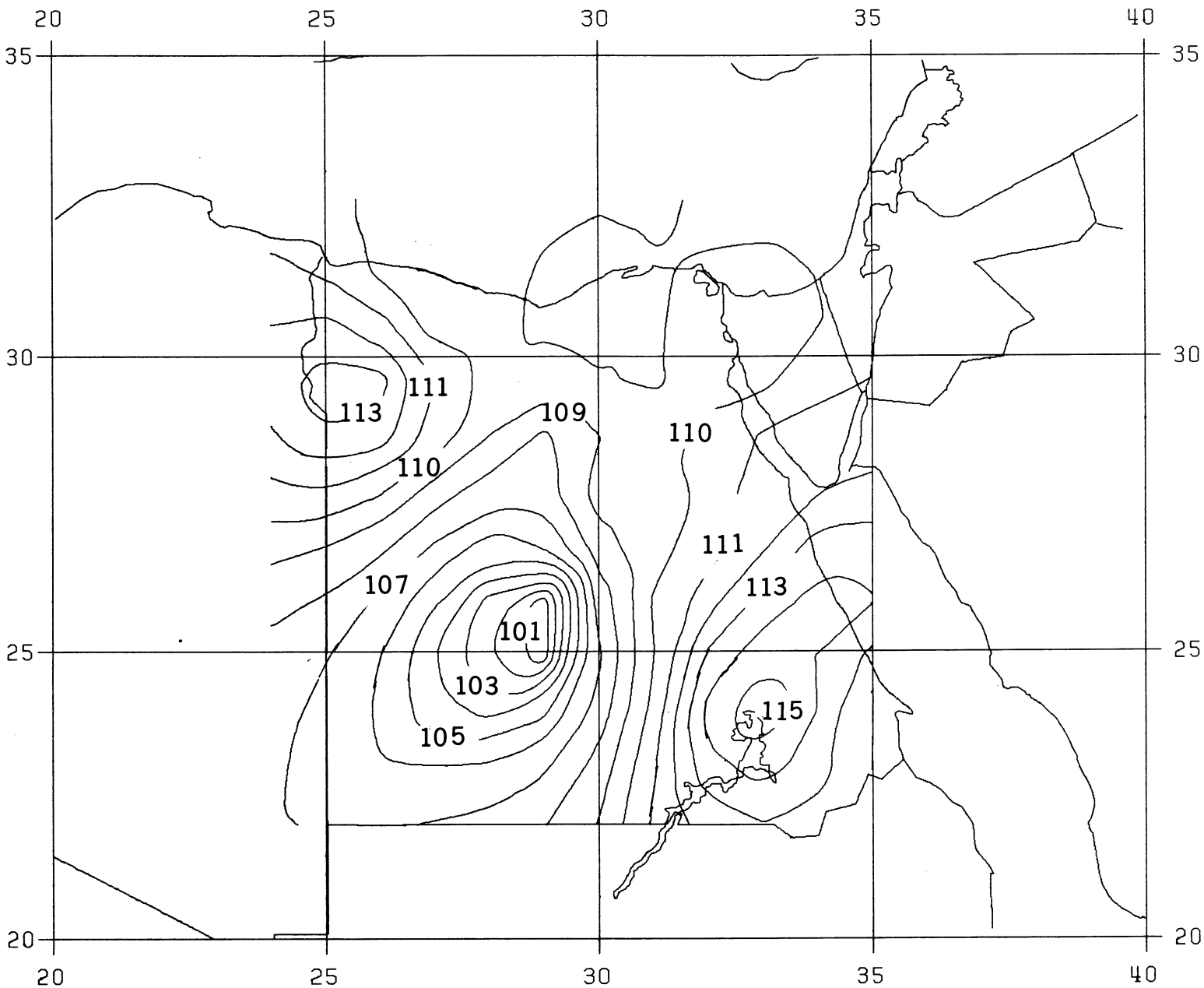

Figure 14.77. Contour Chart - Old Egyptian Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

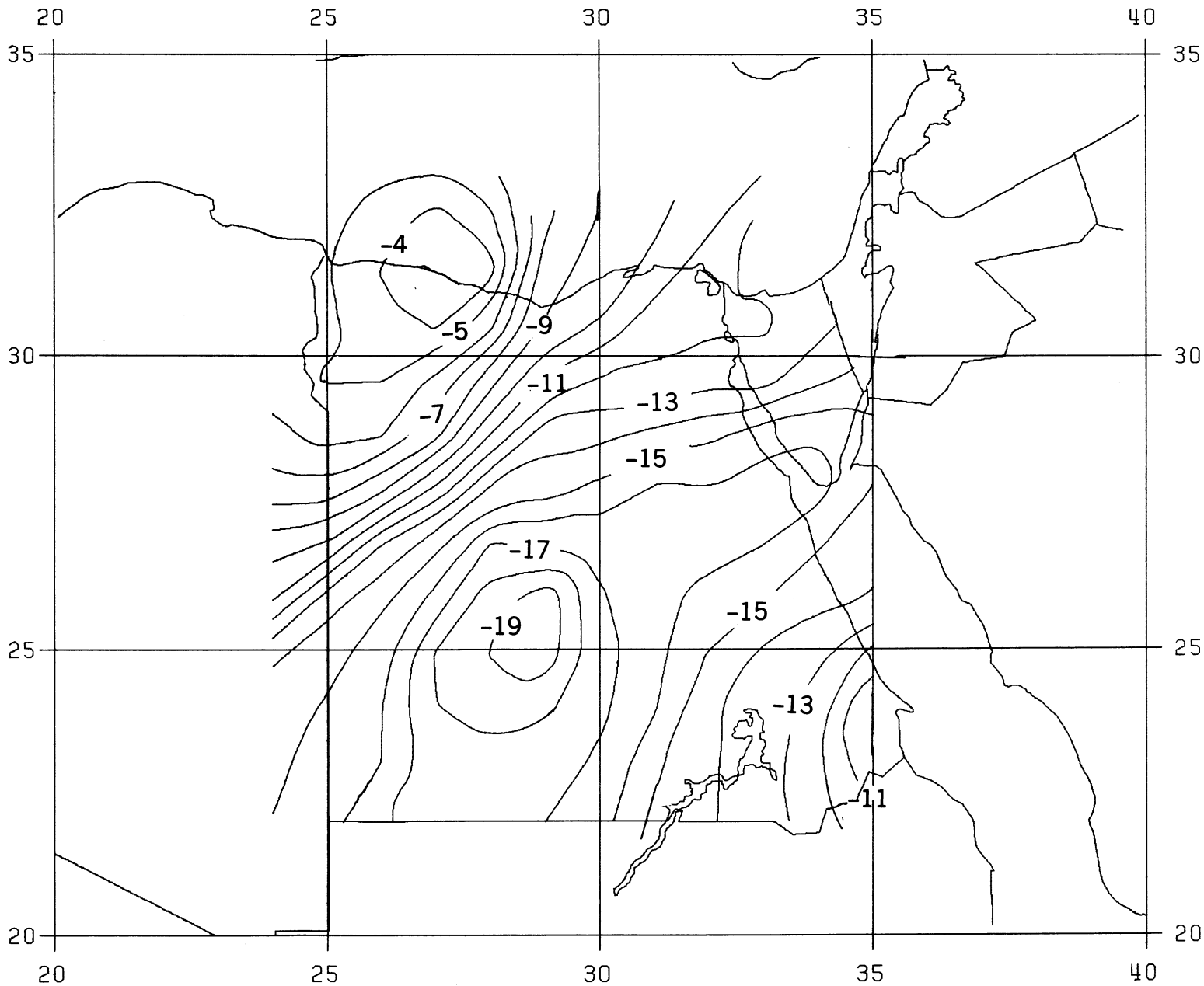

Figure 14.78. Contour Chart - Old Egyptian Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

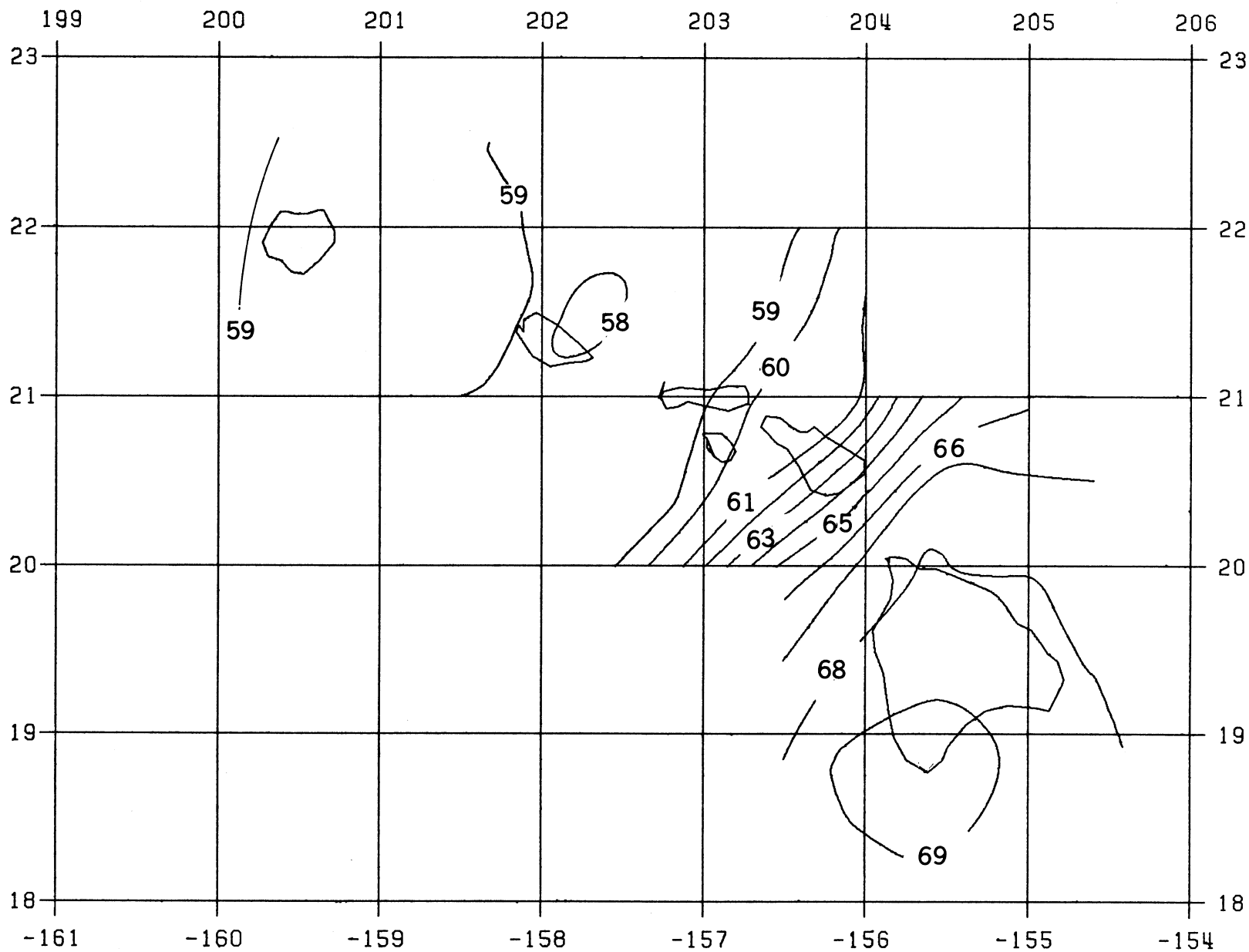

Figure 14.79. Contour Chart - Old Hawaiian Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

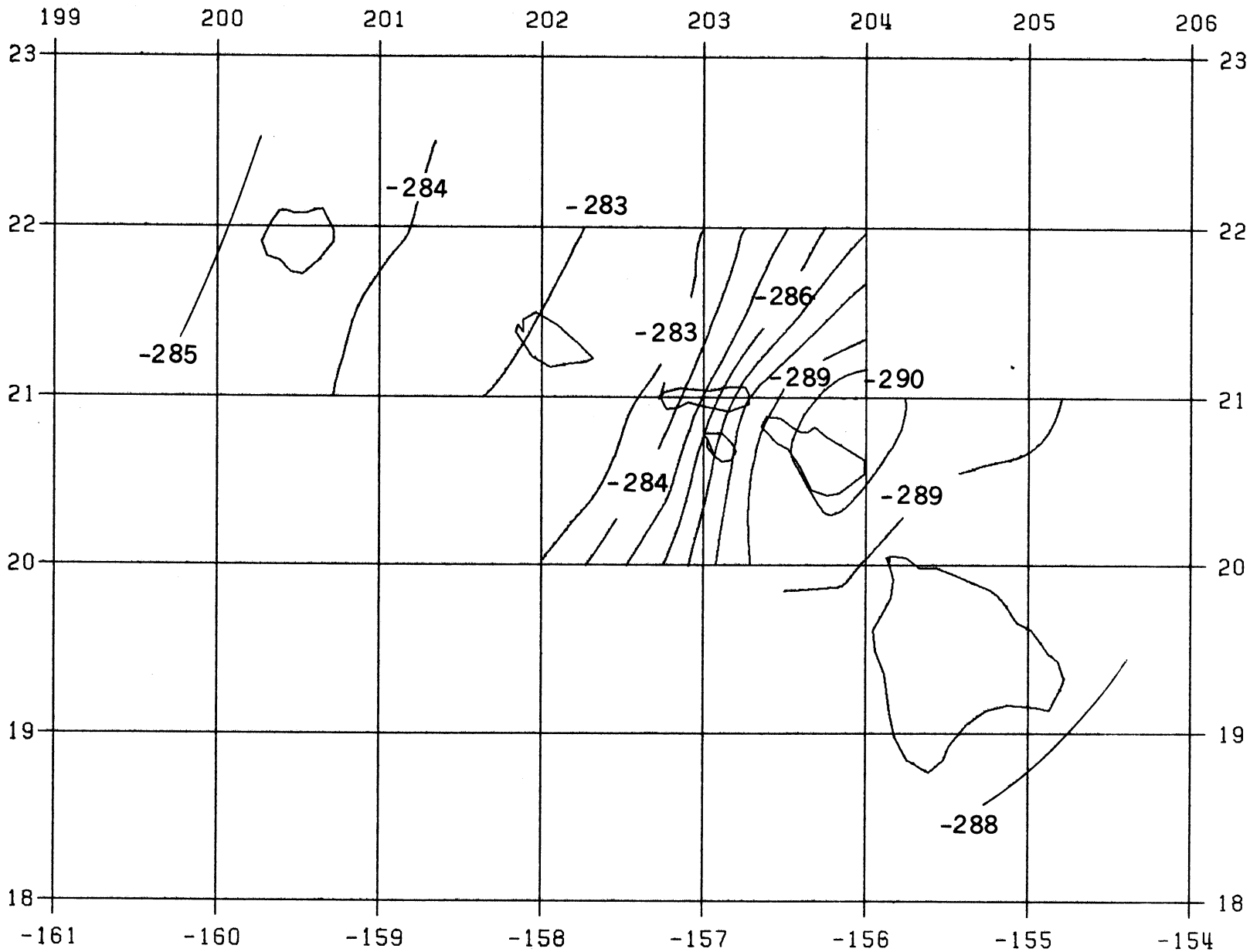

Figure 14.80. Contour Chart - Old Hawaiian Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

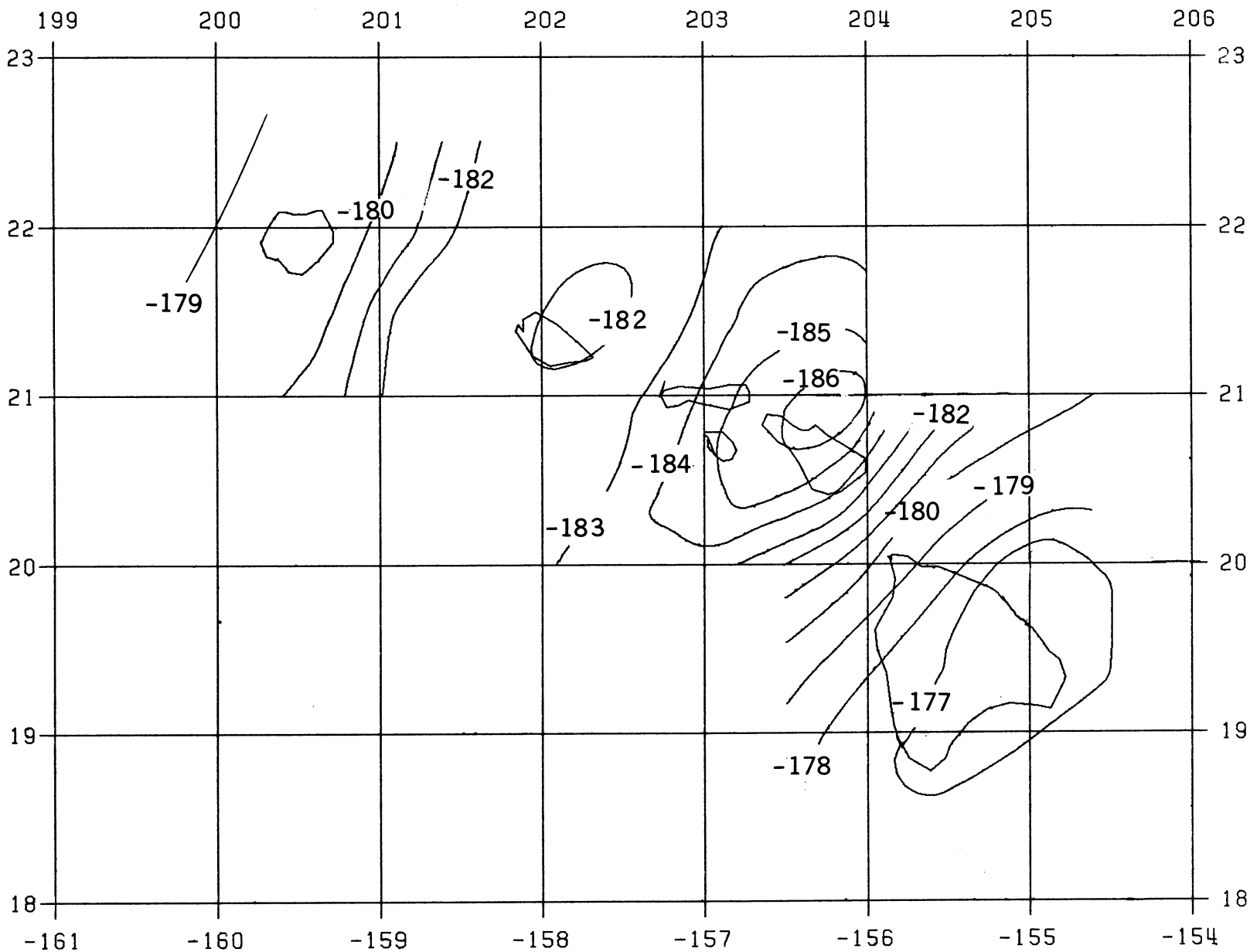

Figure 14.81. Contour Chart - Old Hawaiian Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

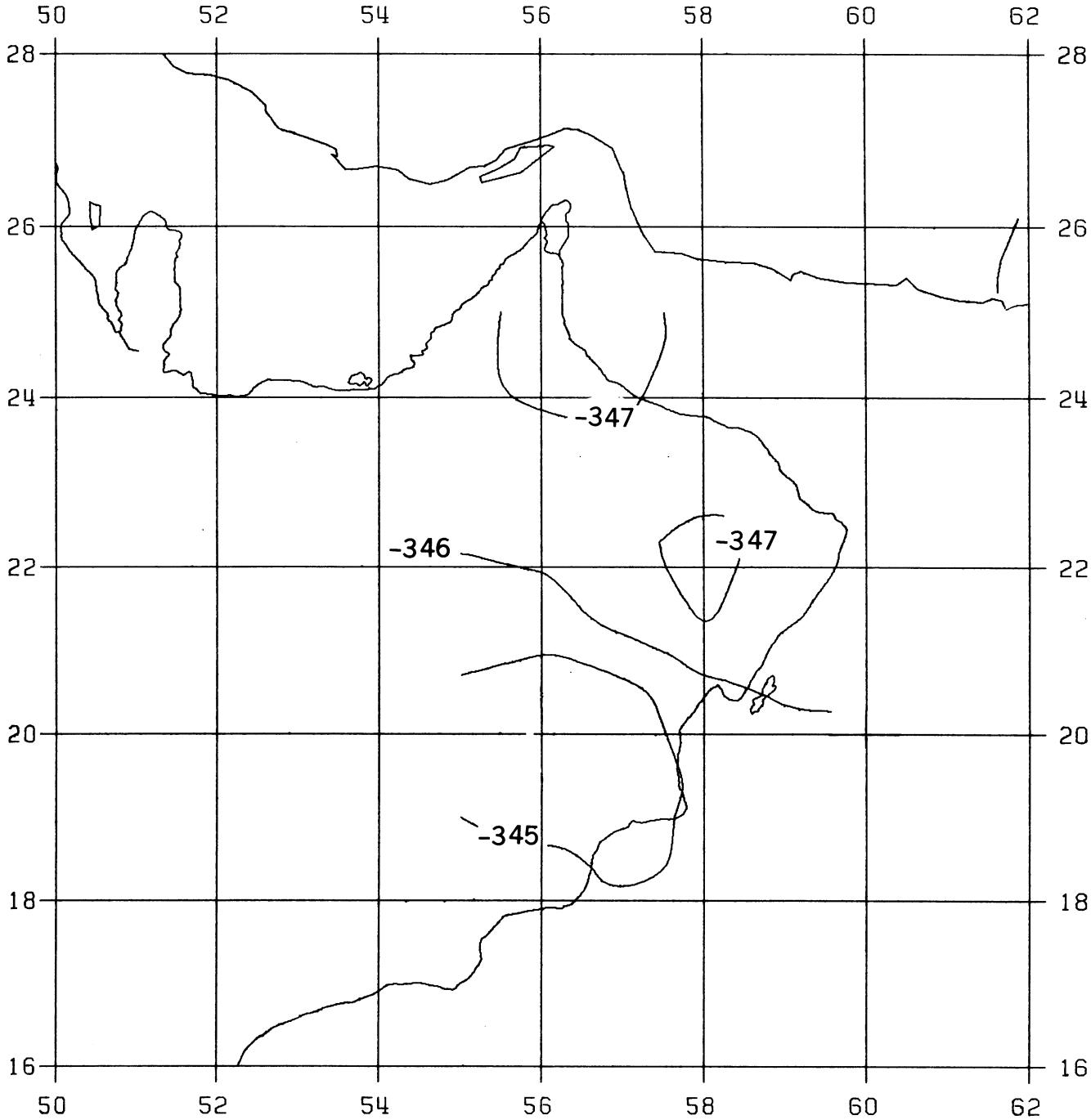

Figure 14.82. Contour Chart - Oman Datum to WGS 84 Datum Shifts, △X Component (Contour Interval = 1 Meter)

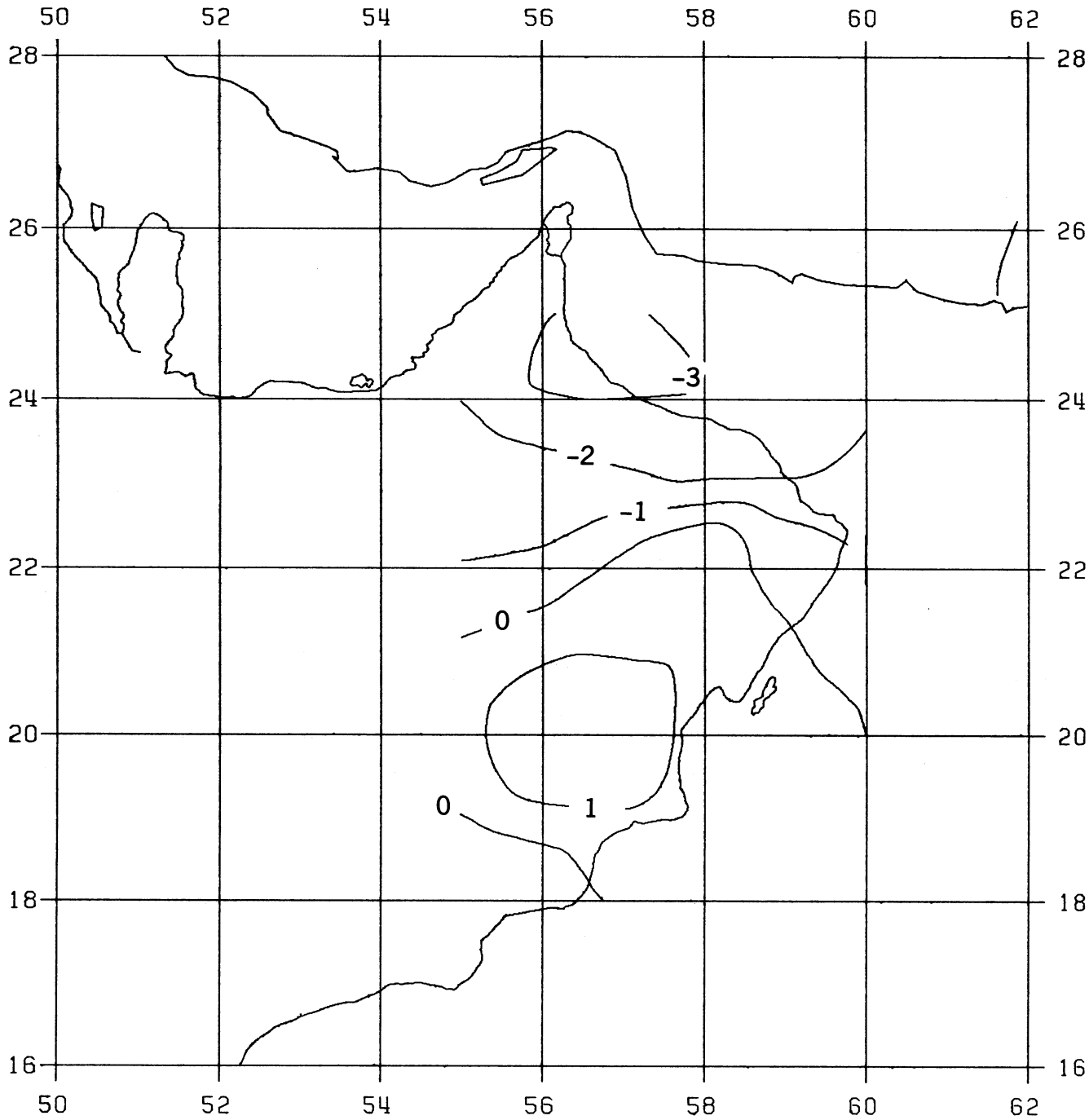

Figure 14.83. Contour Chart - Oman Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

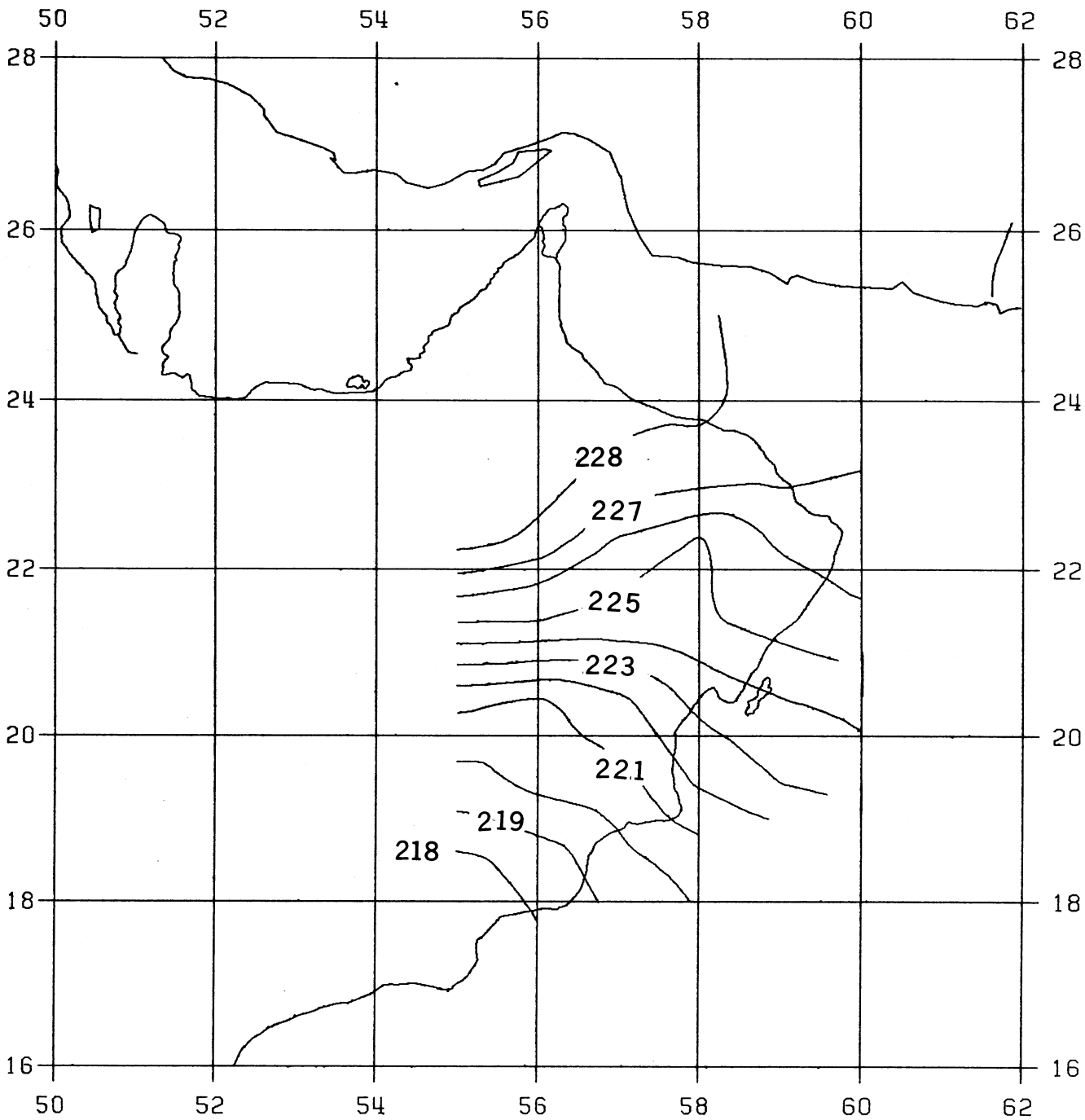

Figure 14.84. Contour Chart - Oman Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

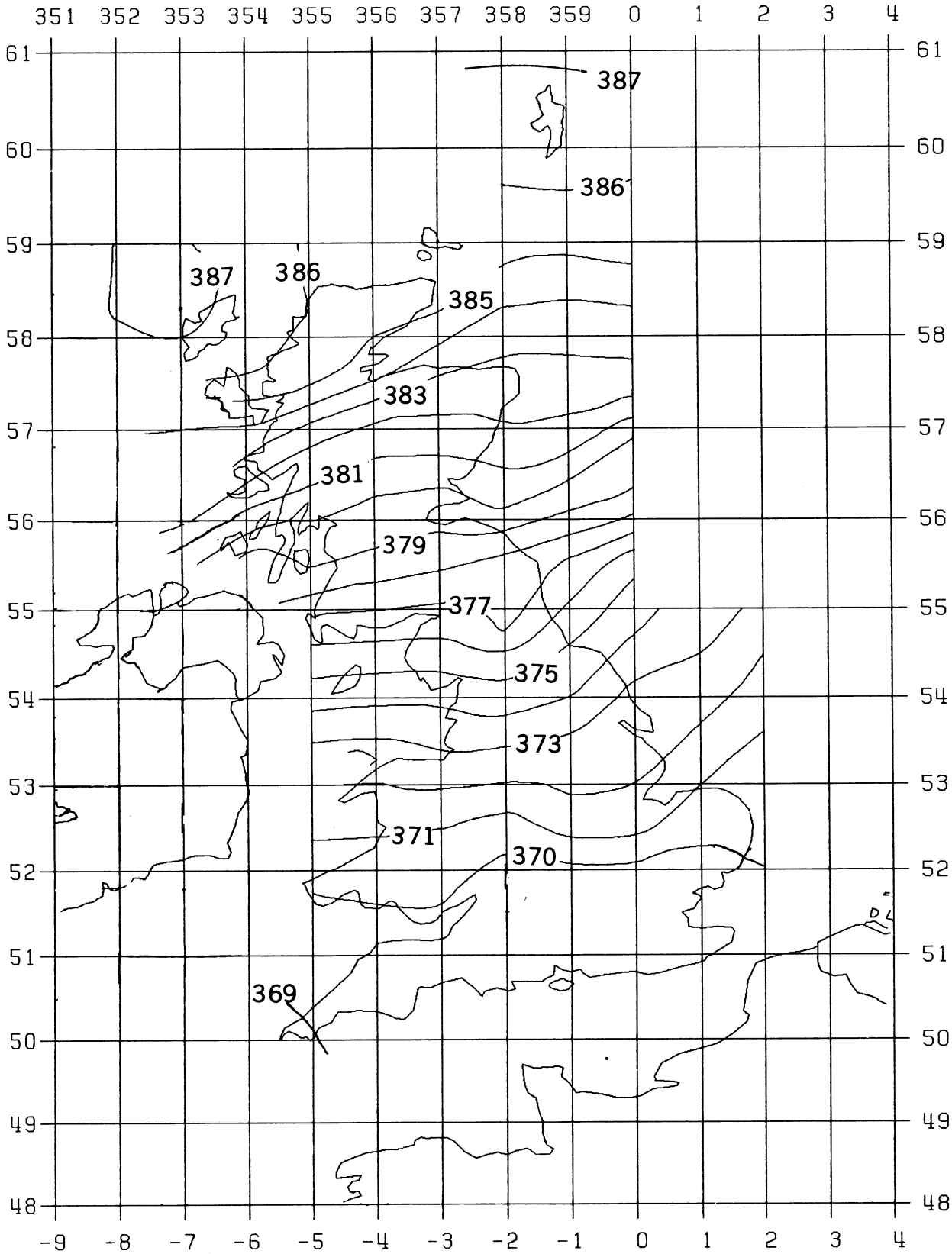

Figure 14.85. Contour Chart - Ordnance Survey of Great Britain 1936 Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

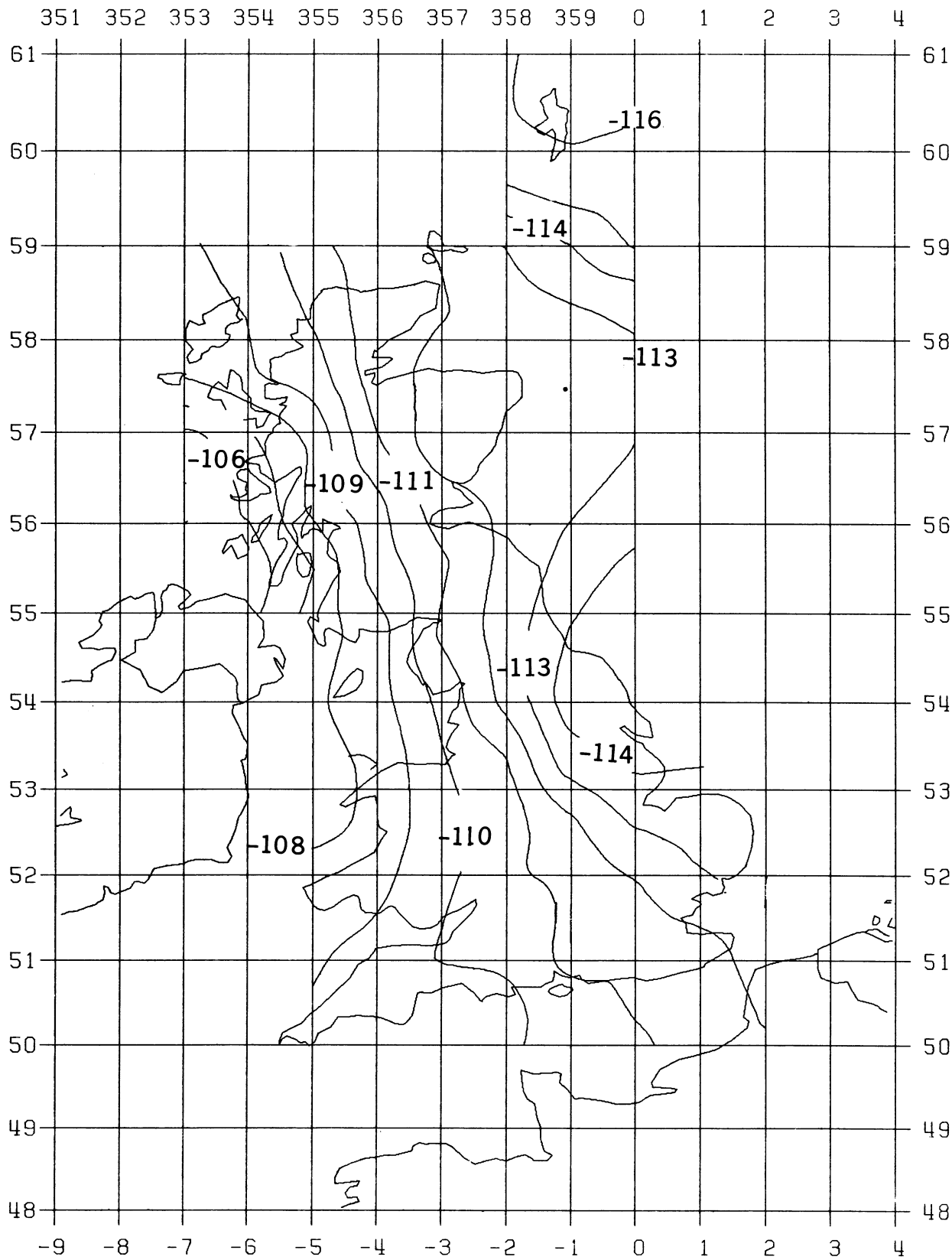

Figure 14.86. Contour Chart -- Ordnance Survey of Great Britain 1936 Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

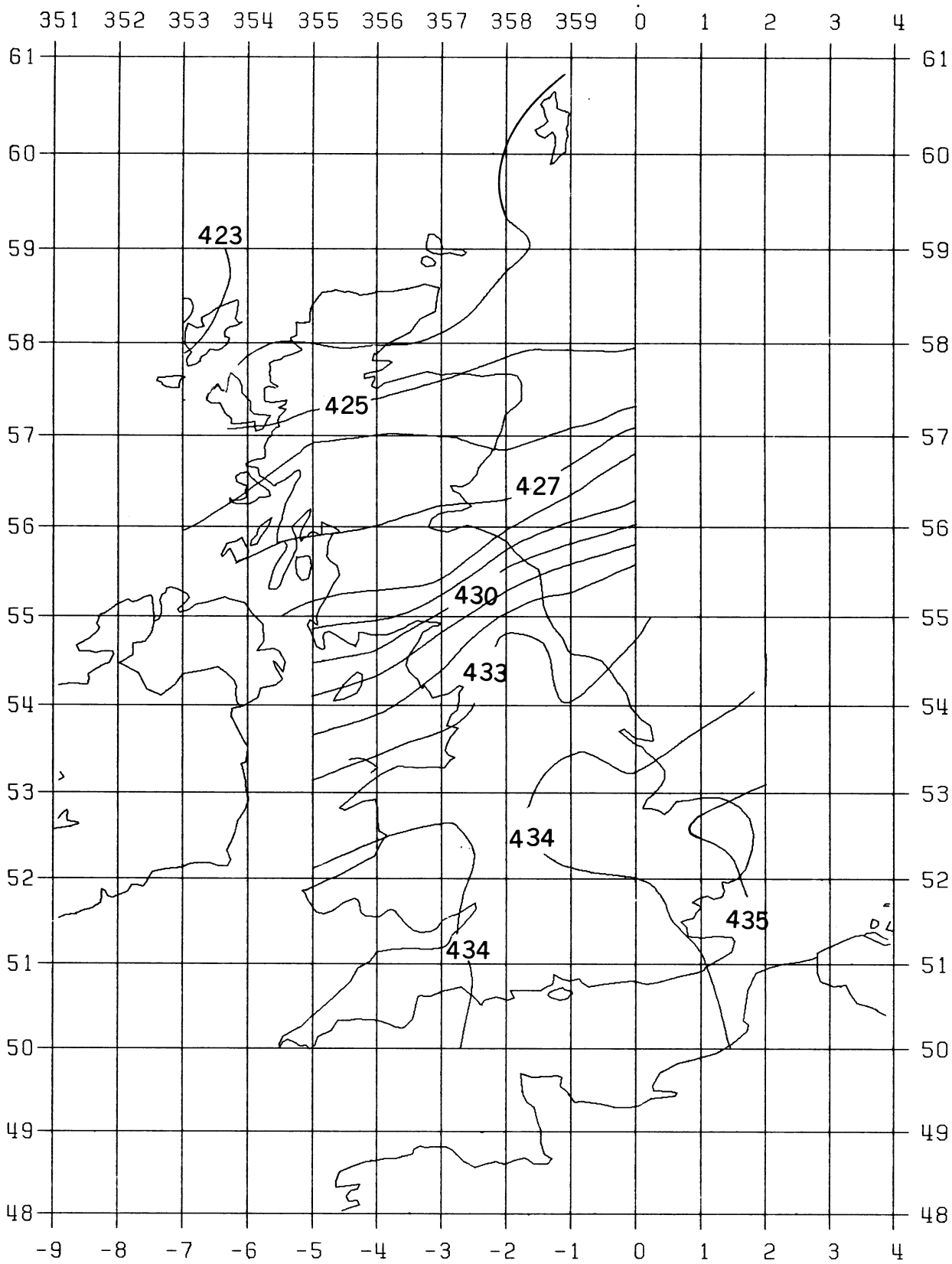

Figure 14.87. Contour Chart - Ordnance Survey of Great Britain 1936 Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

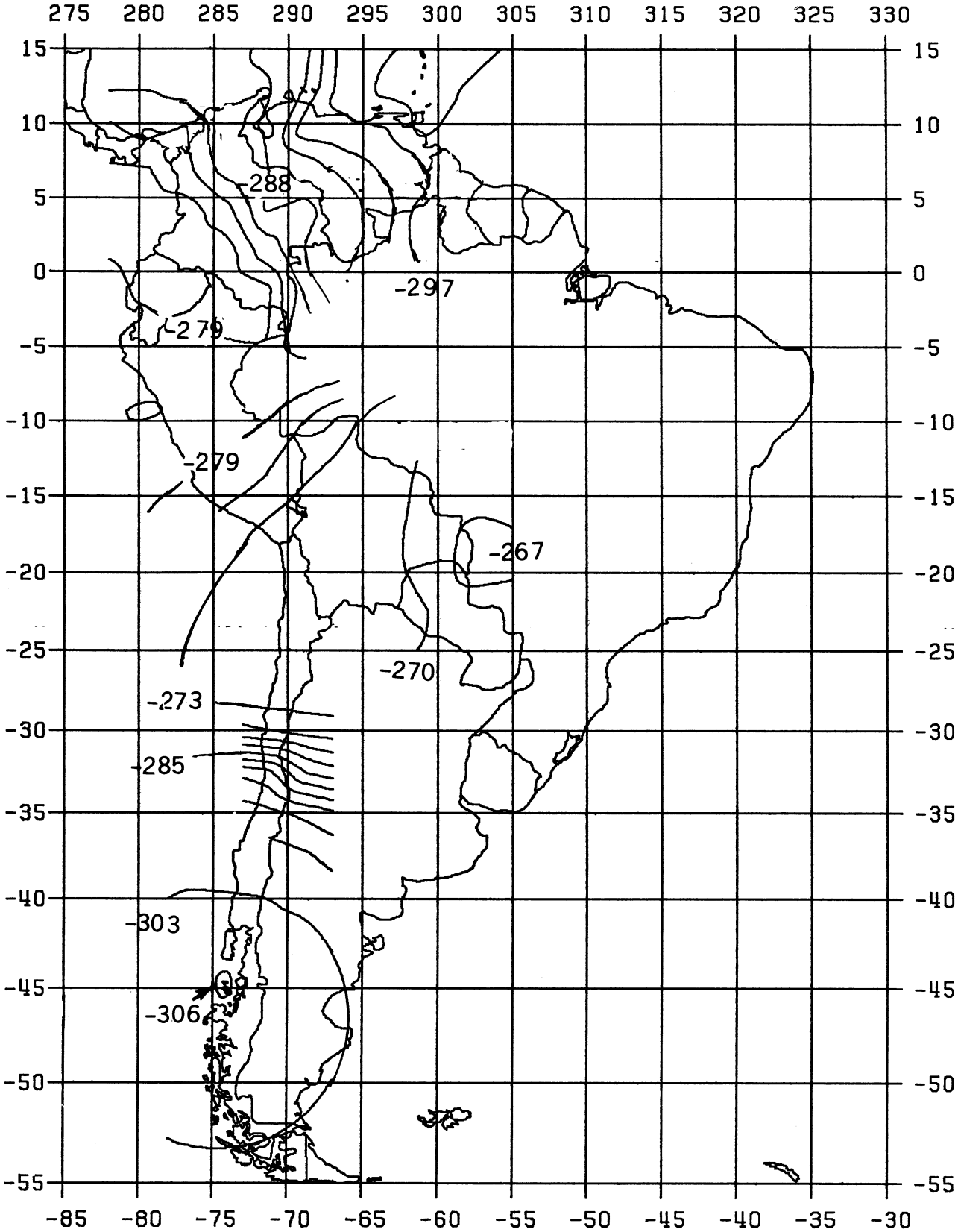

Figure 14.88. Contour Chart - Provisional South American Datum 1956 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 3 Meters)

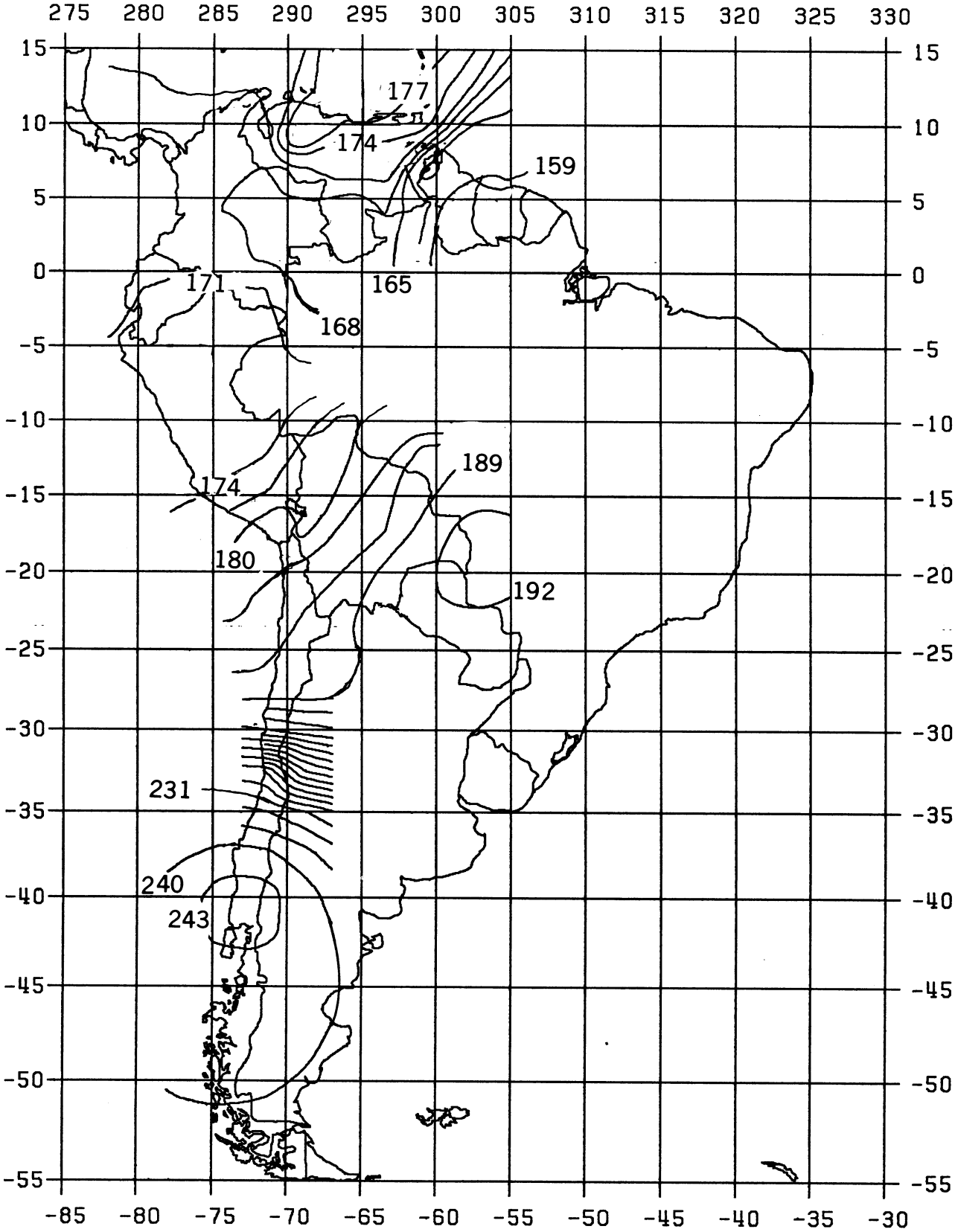

Figure 14.89. Contour Chart – Provisional South American Datum 1956 to WGS 84 Datum Shifts, △Y Component (Contour Interval = 3 Meters)

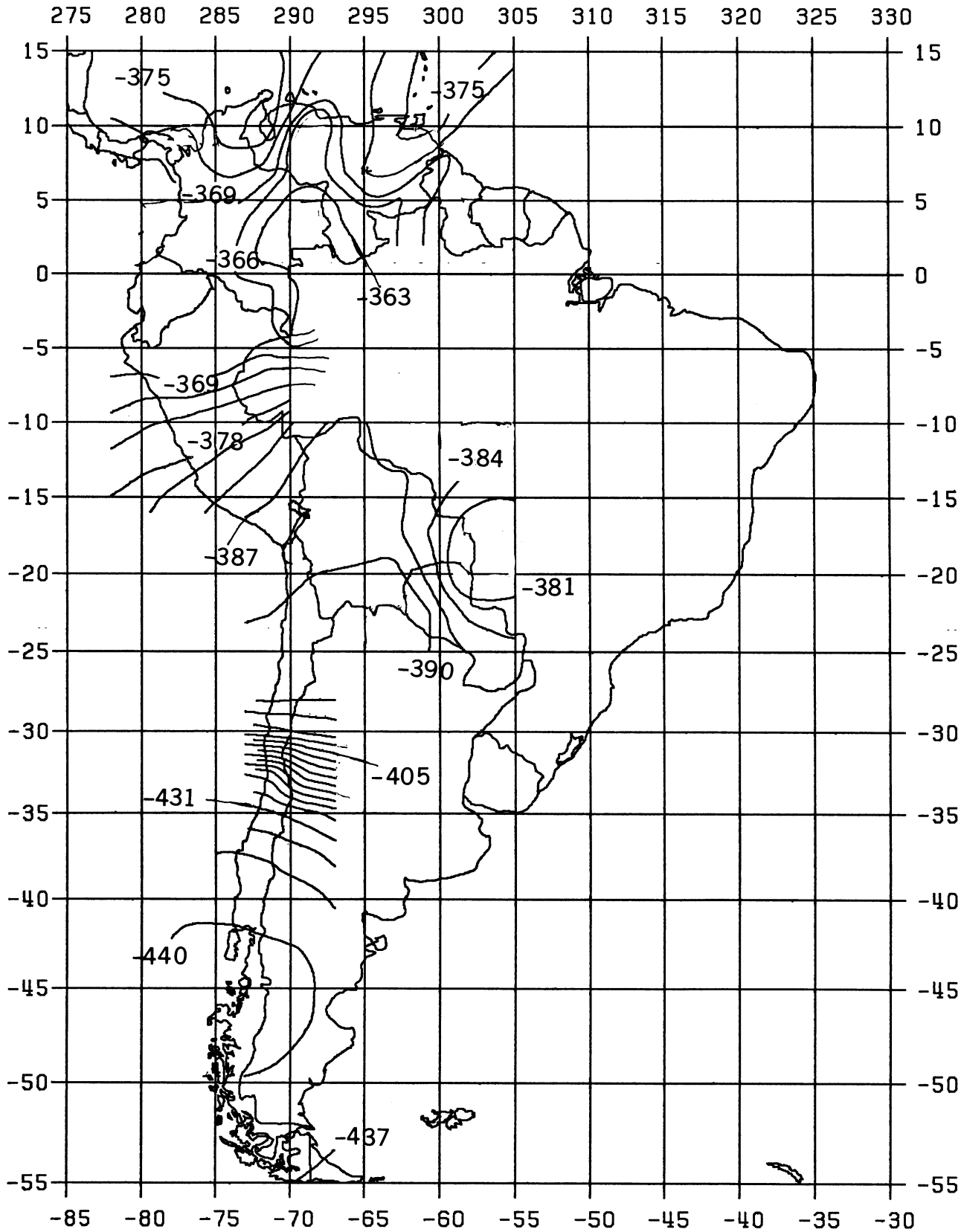

Figure 14.90. Contour Chart - Provisional South American Datum 1956 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 3 Meters)

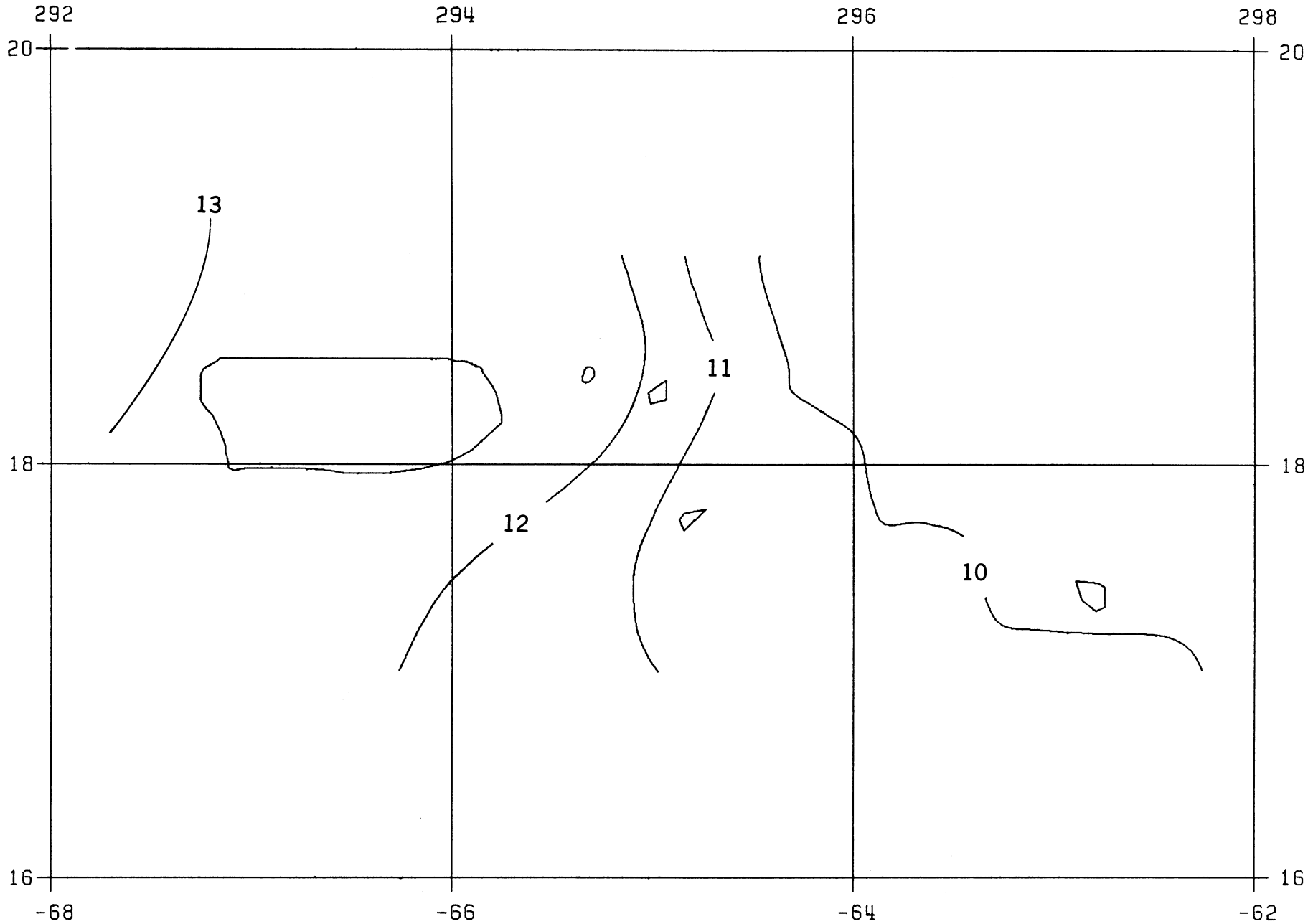

Figure 14.91. Contour Chart - Puerto Rico Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

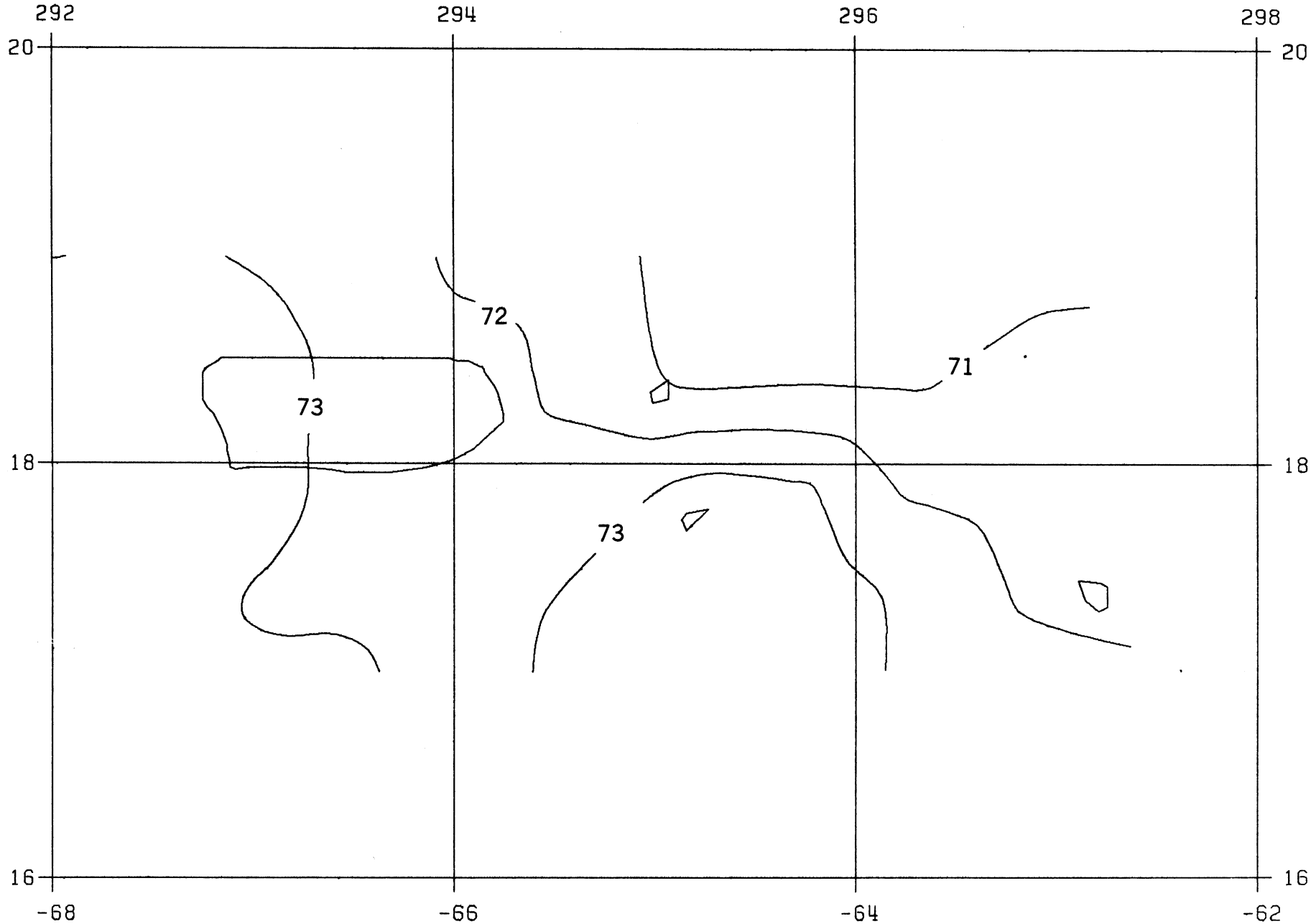

Figure 14.92. Contour Chart – Puerto Rico Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

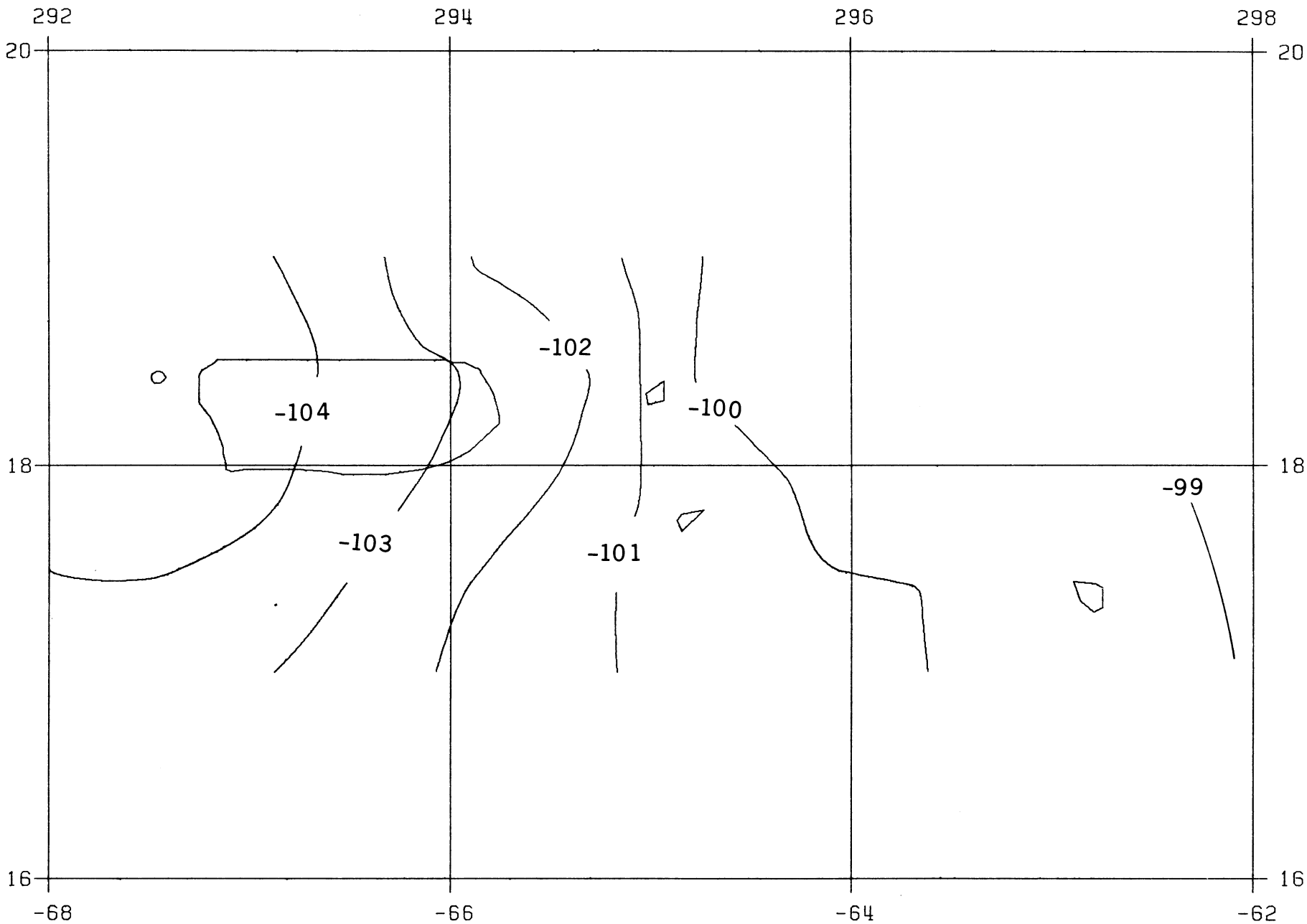

Figure 14.93. Contour Chart - Puerto Rico Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

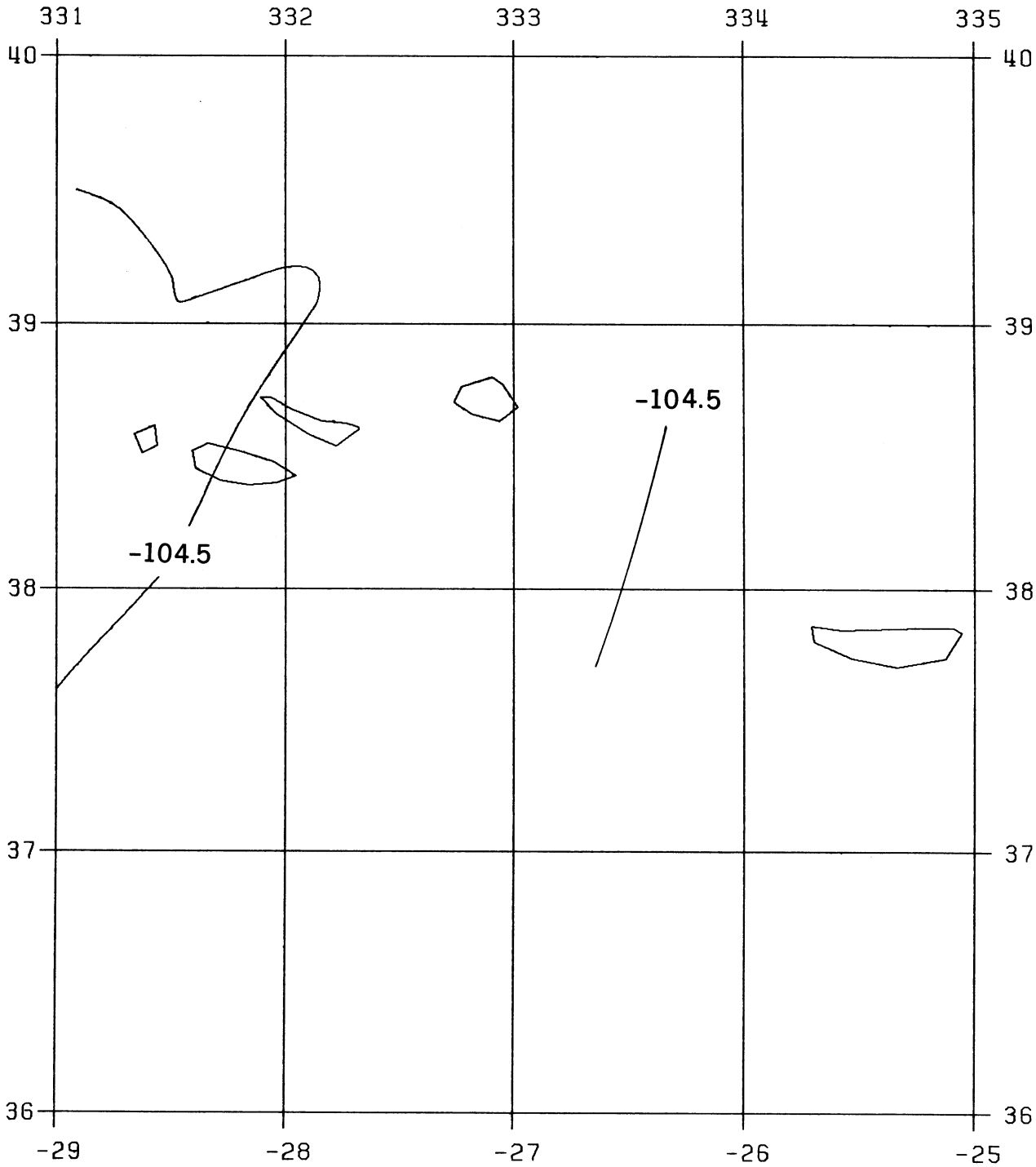

Figure 14.94. Contour Chart – Southwest Base Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 0.5 Meter)

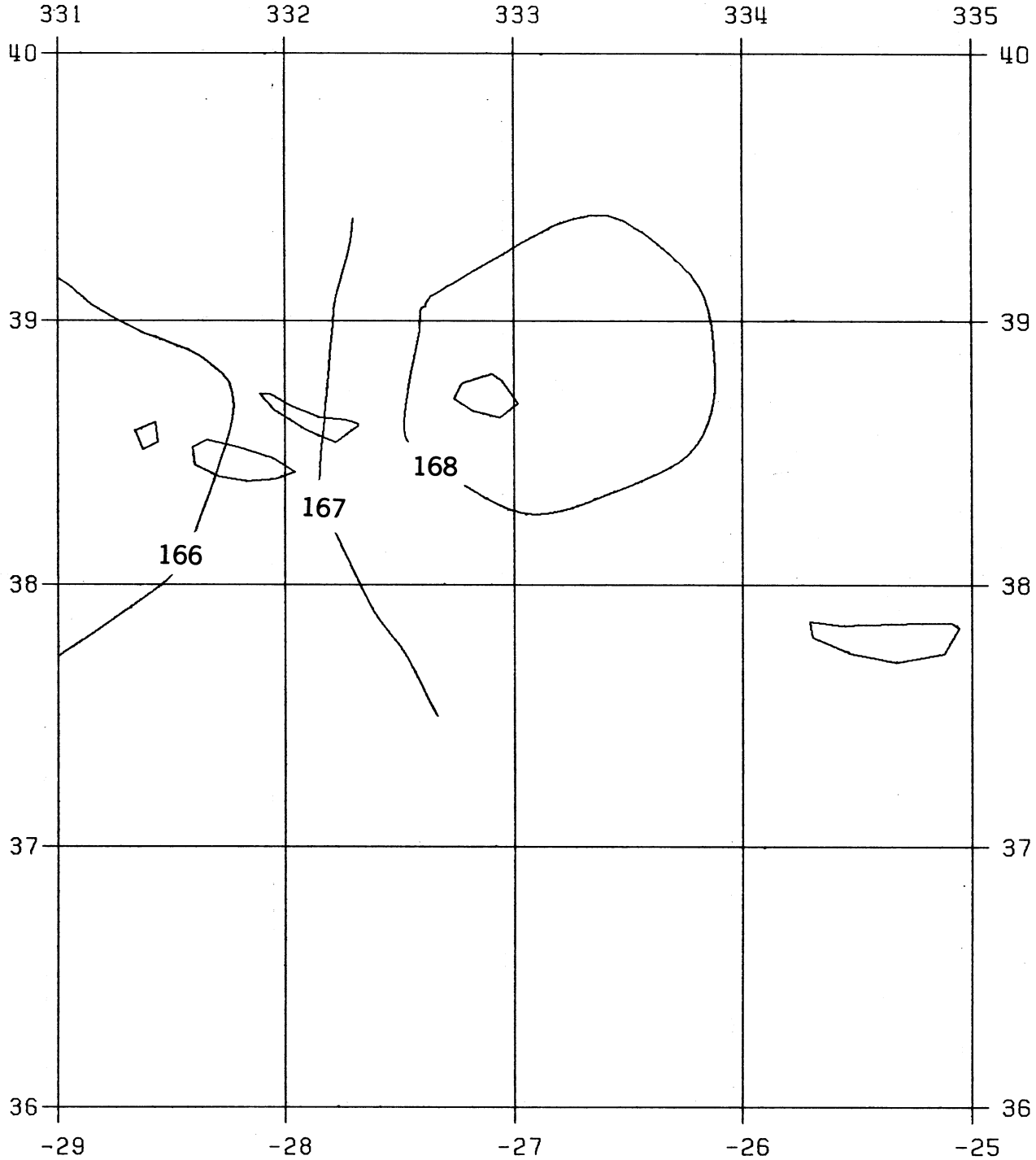

Figure 14.95. Contour Chart - Southwest Base Datum to WGS 84 Datum Shifts, △Y Component (Contour Interval = 1 Meter)

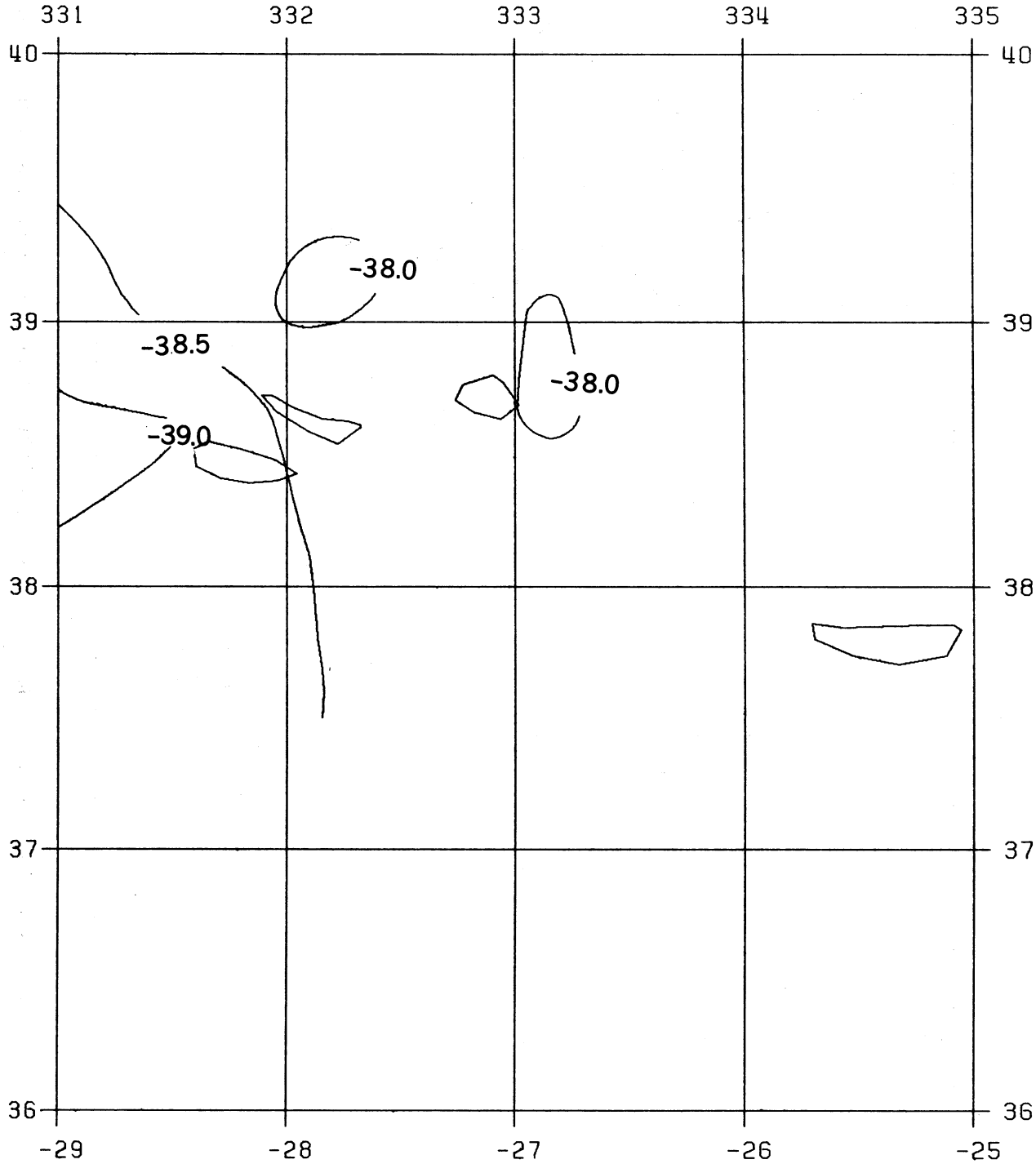

Figure 14.96. Contour Chart - Southwest Base Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 0.5 Meter)

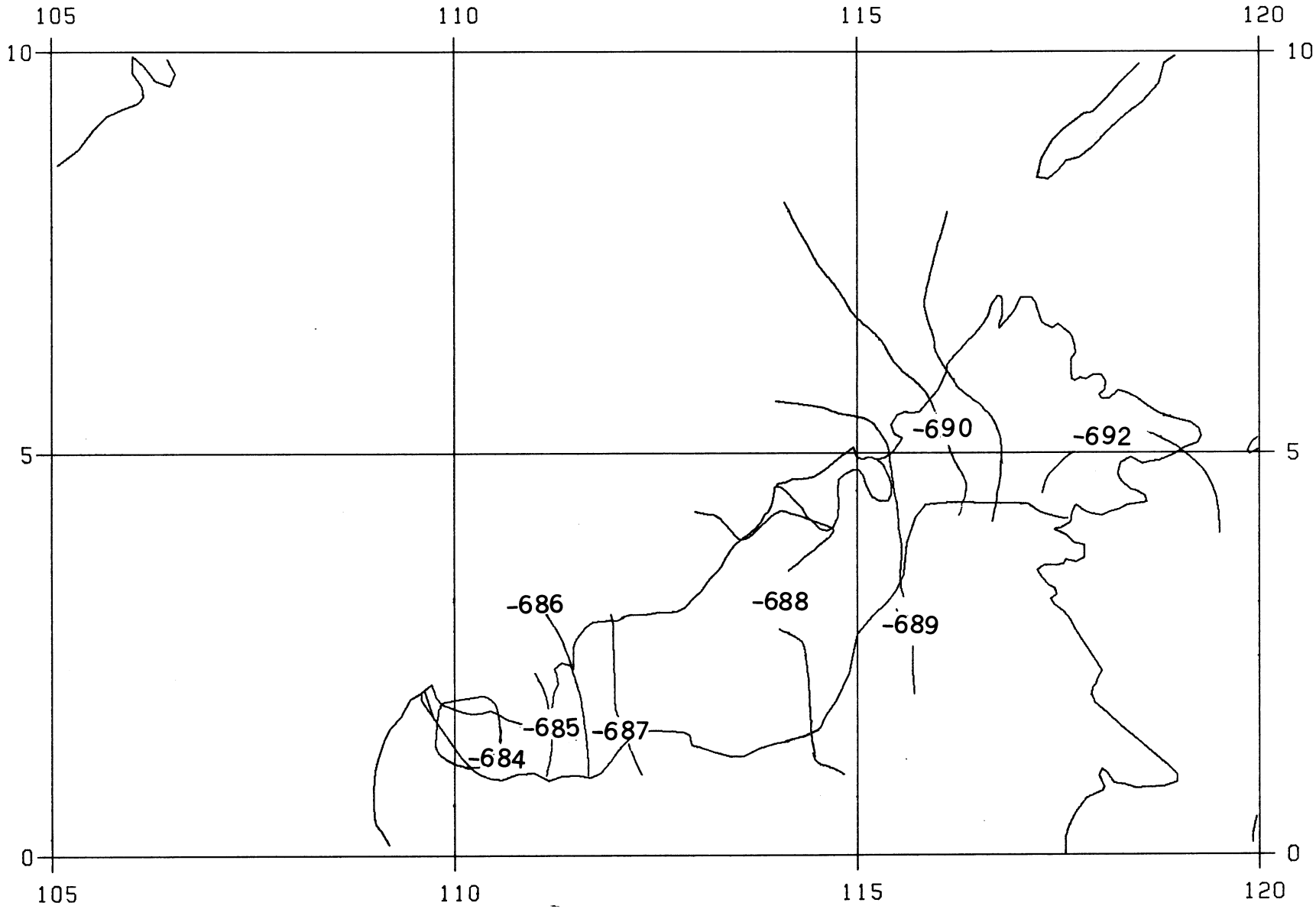

Figure 14.97. Contour Chart - Timbalai Datum 1948 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

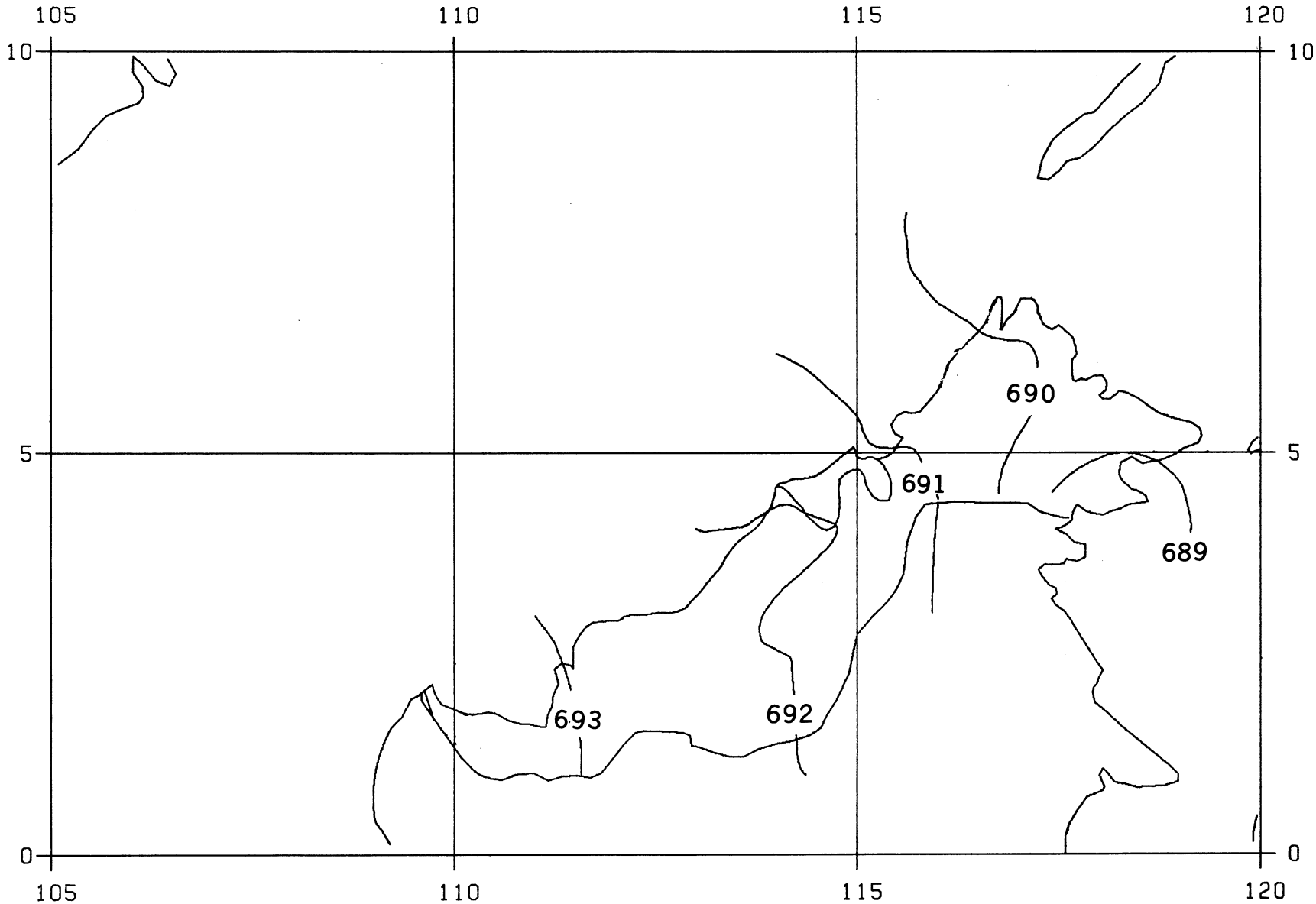

Figure 14.98. Contour Chart - Timbalai Datum 1948 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

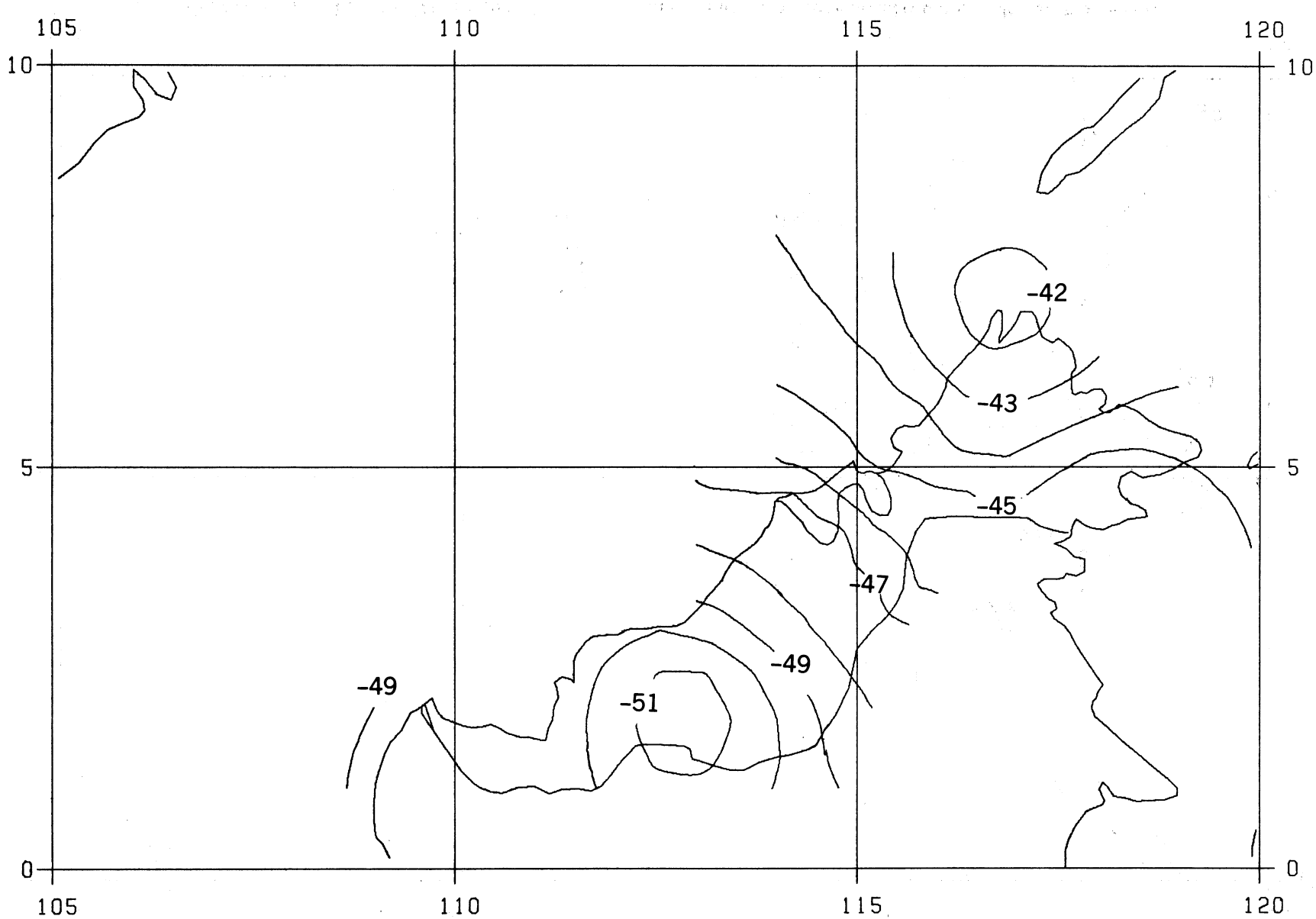

Figure 14.99. Contour Chart - Timbalai Datum 1948 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

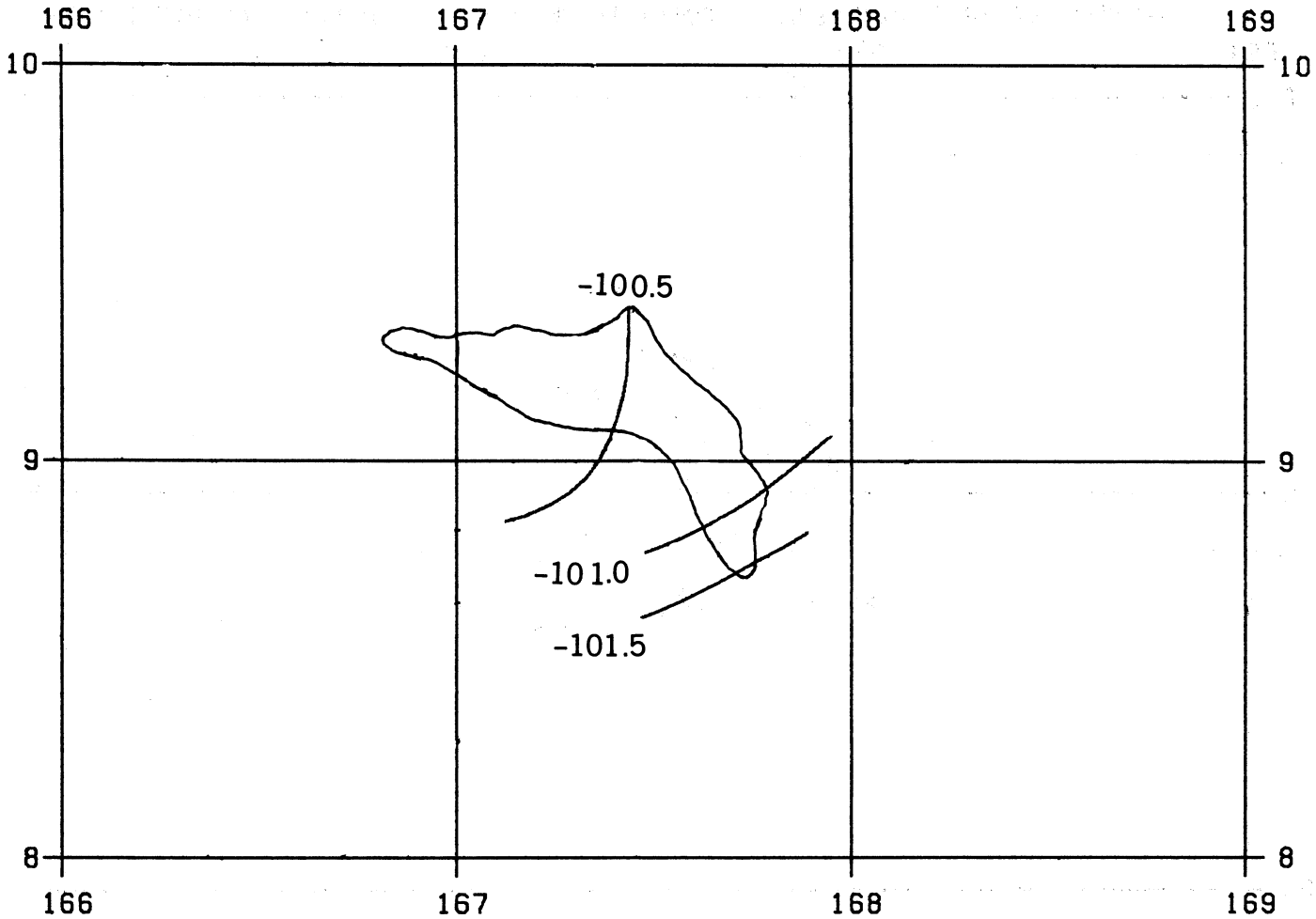

Figure 14.100. Contour Chart - Wake-Eniwetok Datum 1960 to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 0.5 Meter)

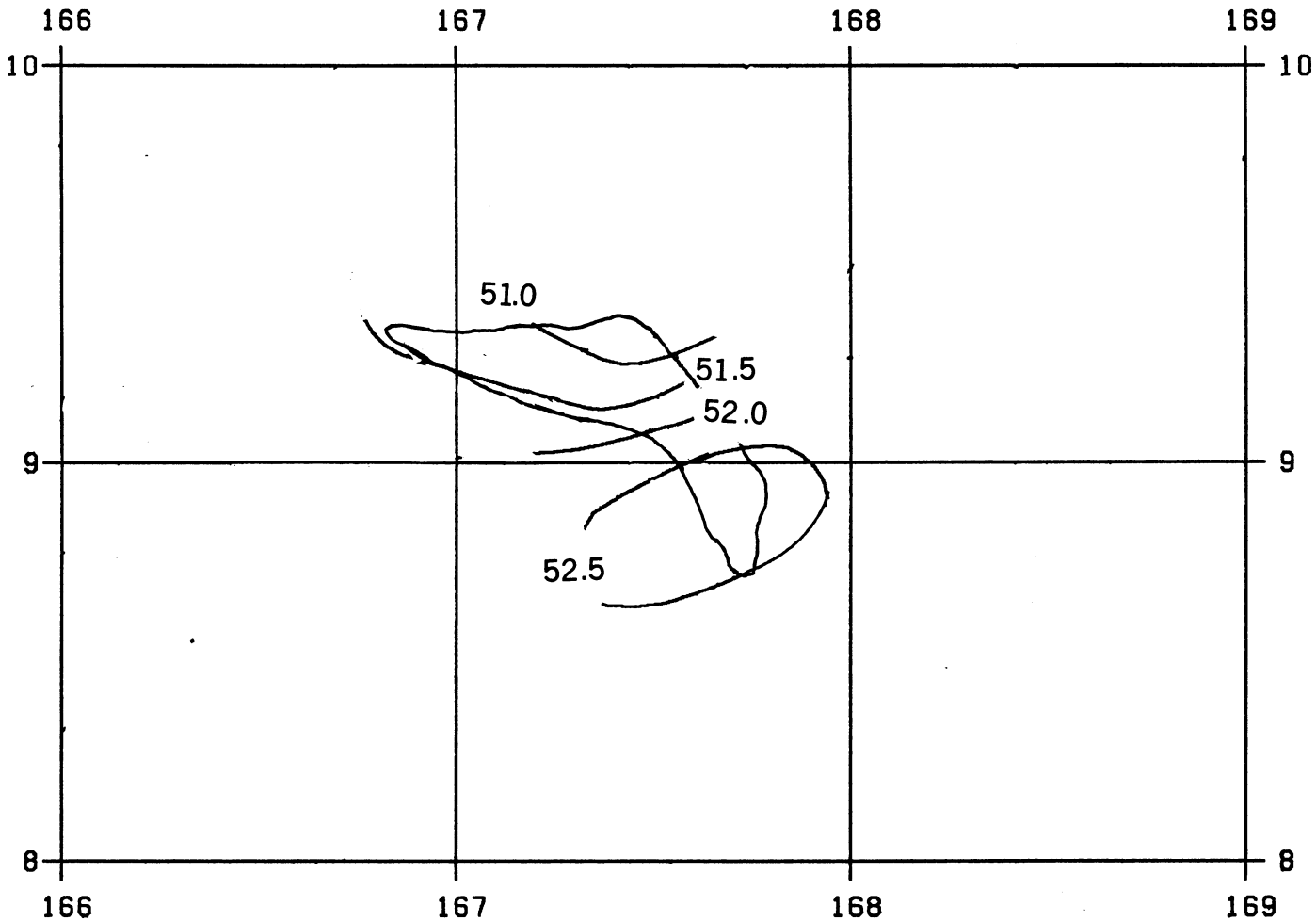

Figure 14.101. Contour Chart – Wake-Eniwetok Datum 1960 to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 0.5 Meter)

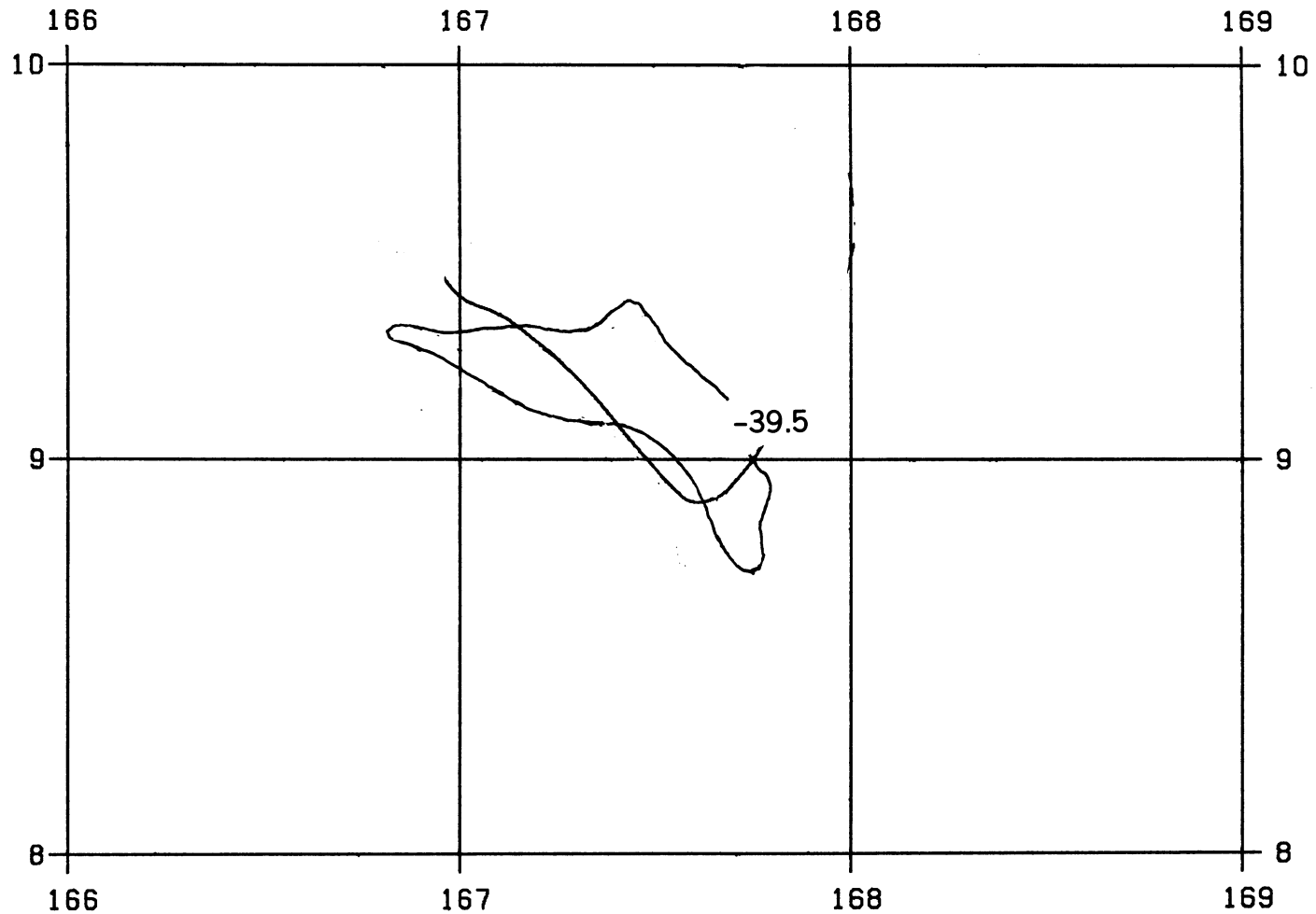

Figure 14.102. Contour Chart – Wake-Eniwetok Datum 1960 to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 0.5 Meter)

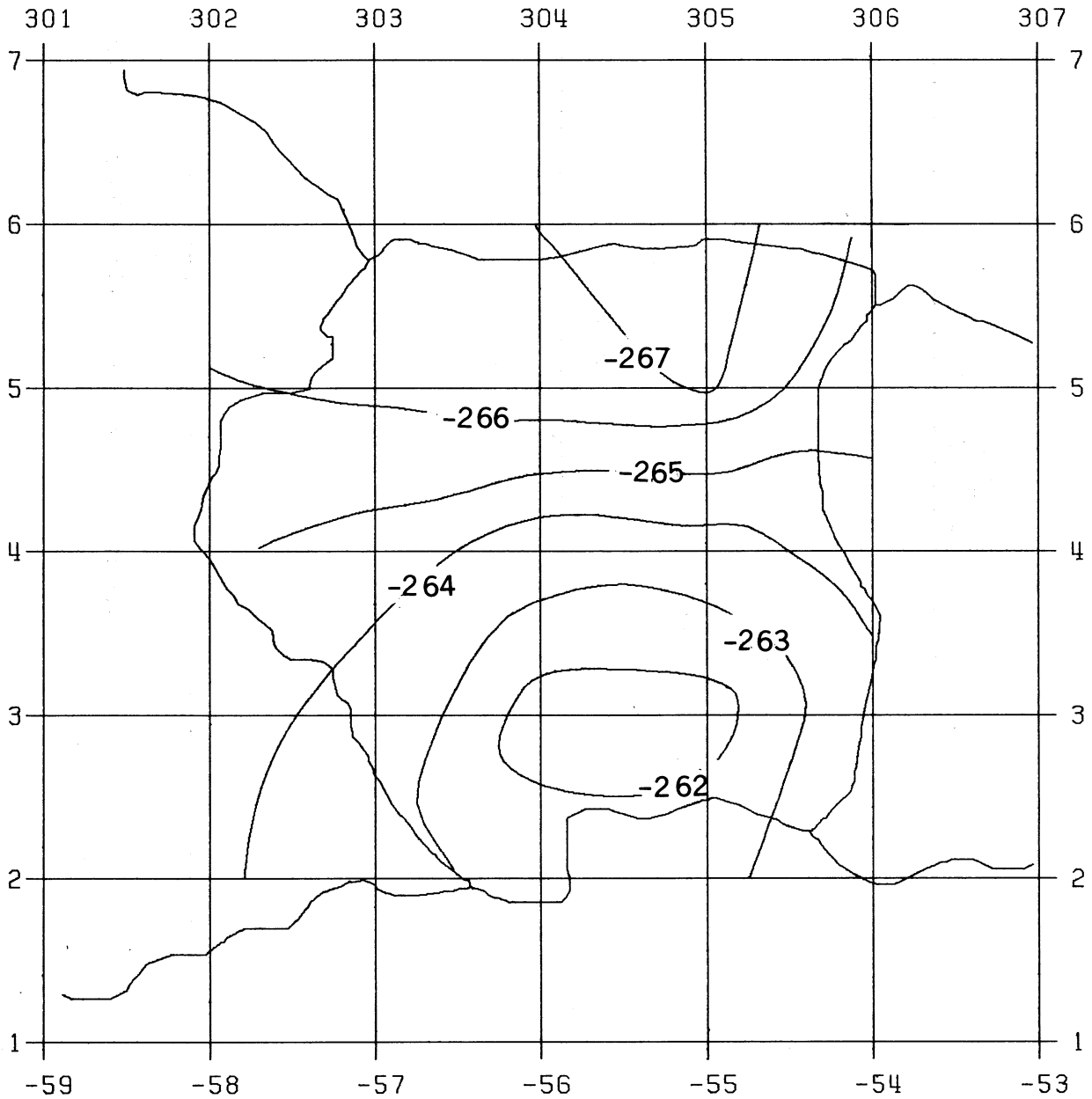

Figure 14.103. Contour Chart - Zanderij Datum to WGS 84 Datum Shifts, ΔX Component (Contour Interval = 1 Meter)

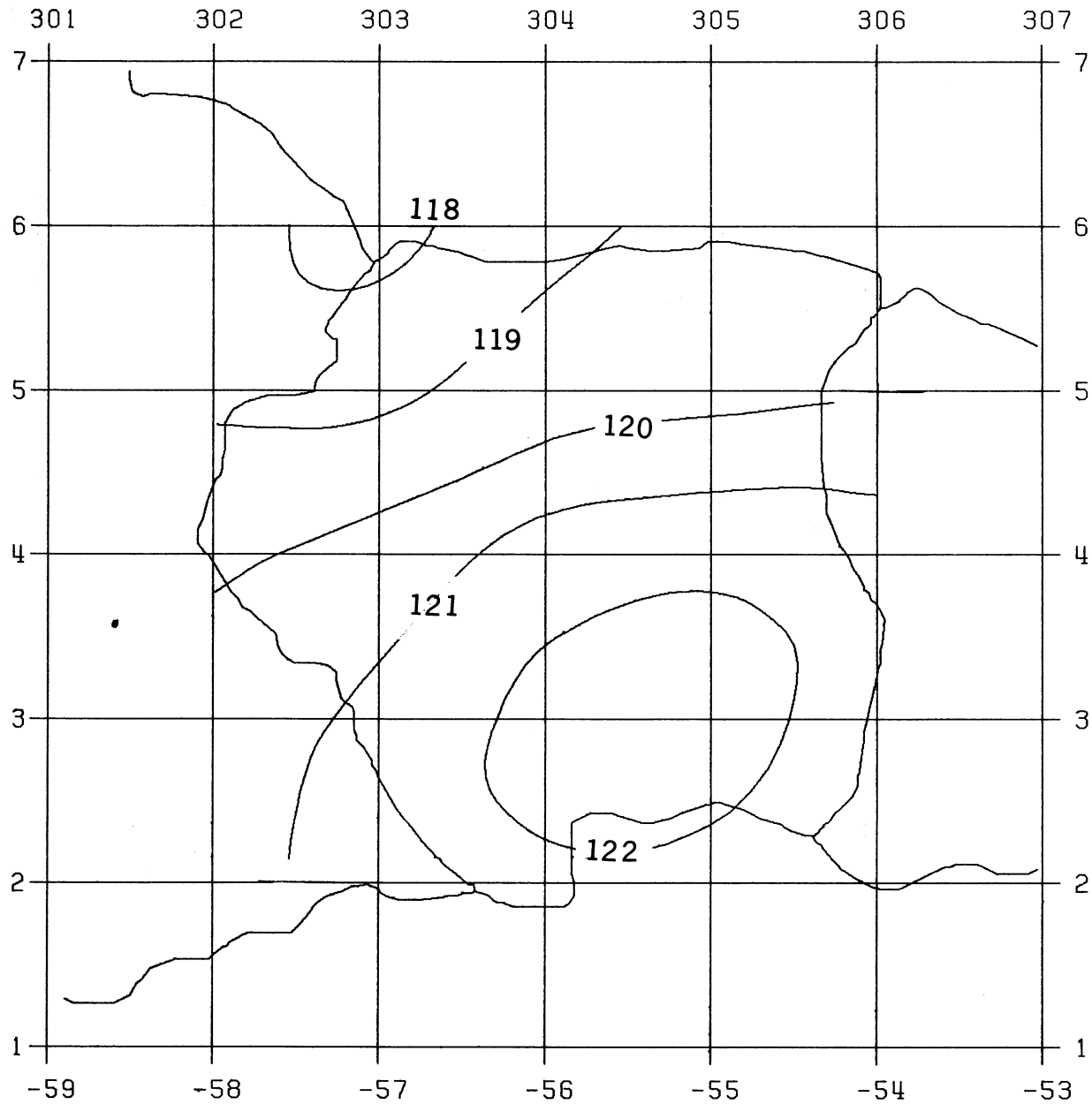

Figure 14.104. Contour Chart - Zanderij Datum to WGS 84 Datum Shifts, ΔY Component (Contour Interval = 1 Meter)

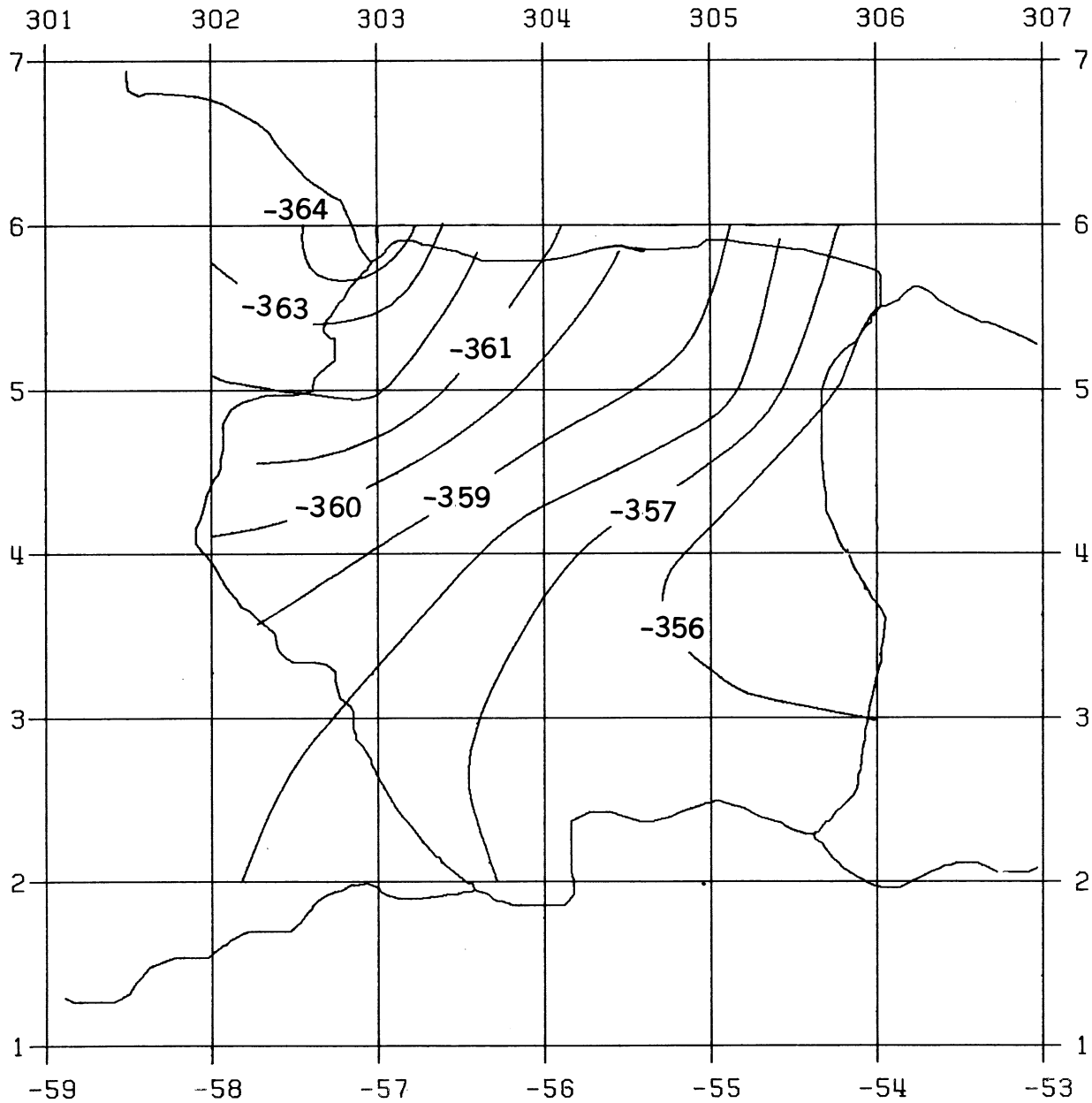

Figure 14.105. Contour Chart - Zanderij Datum to WGS 84 Datum Shifts, ΔZ Component (Contour Interval = 1 Meter)

SECTION 15

LOCAL GEODETIC SYSTEM-TO-WGS 84 DATUM SHIFTS

- $\Delta\phi$, $\Delta\lambda$, ΔH CONTOUR CHARTS FOR MAJOR DATUMS - *

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* THE $\Delta\phi$, $\Delta\lambda$, ΔH VALUES MAY BE USED IN THE FORMULAS:

$$\phi_{WGS\ 84} = \phi_{LGS} + \Delta\phi$$

$$\lambda_{WGS\ 84} = \lambda_{LGS} + \Delta\lambda$$

$$H_{WGS\ 84} = H_{LGS} + \Delta H$$

ϕ, λ, H = GEODETIC LATITUDE, LONGITUDE, HEIGHT
LGS = LOCAL GEODETIC SYSTEM

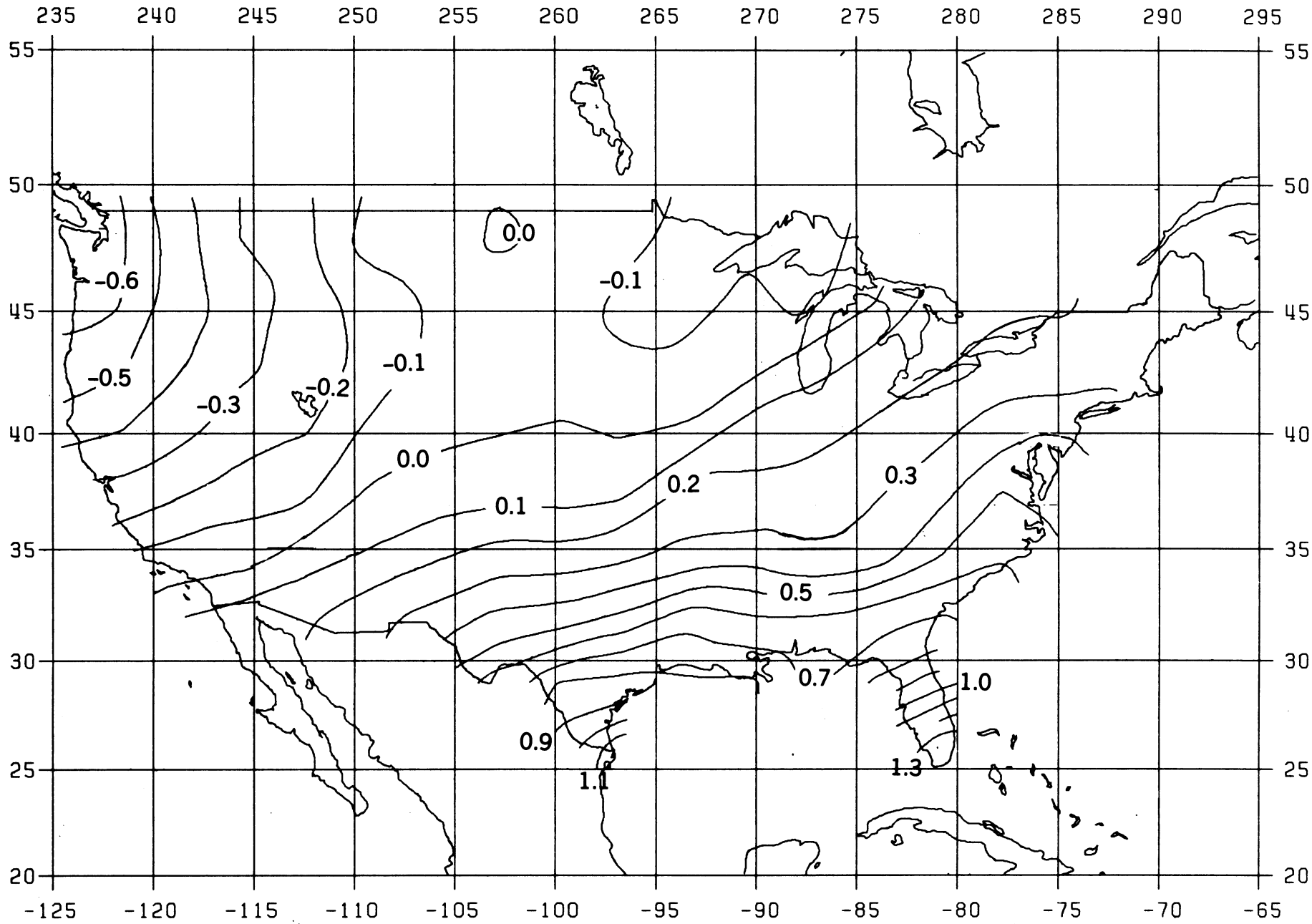

Figure 15.1. Contour Chart–Latitude Differences, WGS 84 Minus NAD 27 (CONUS; Contour Interval = 0.1 Arc Second)

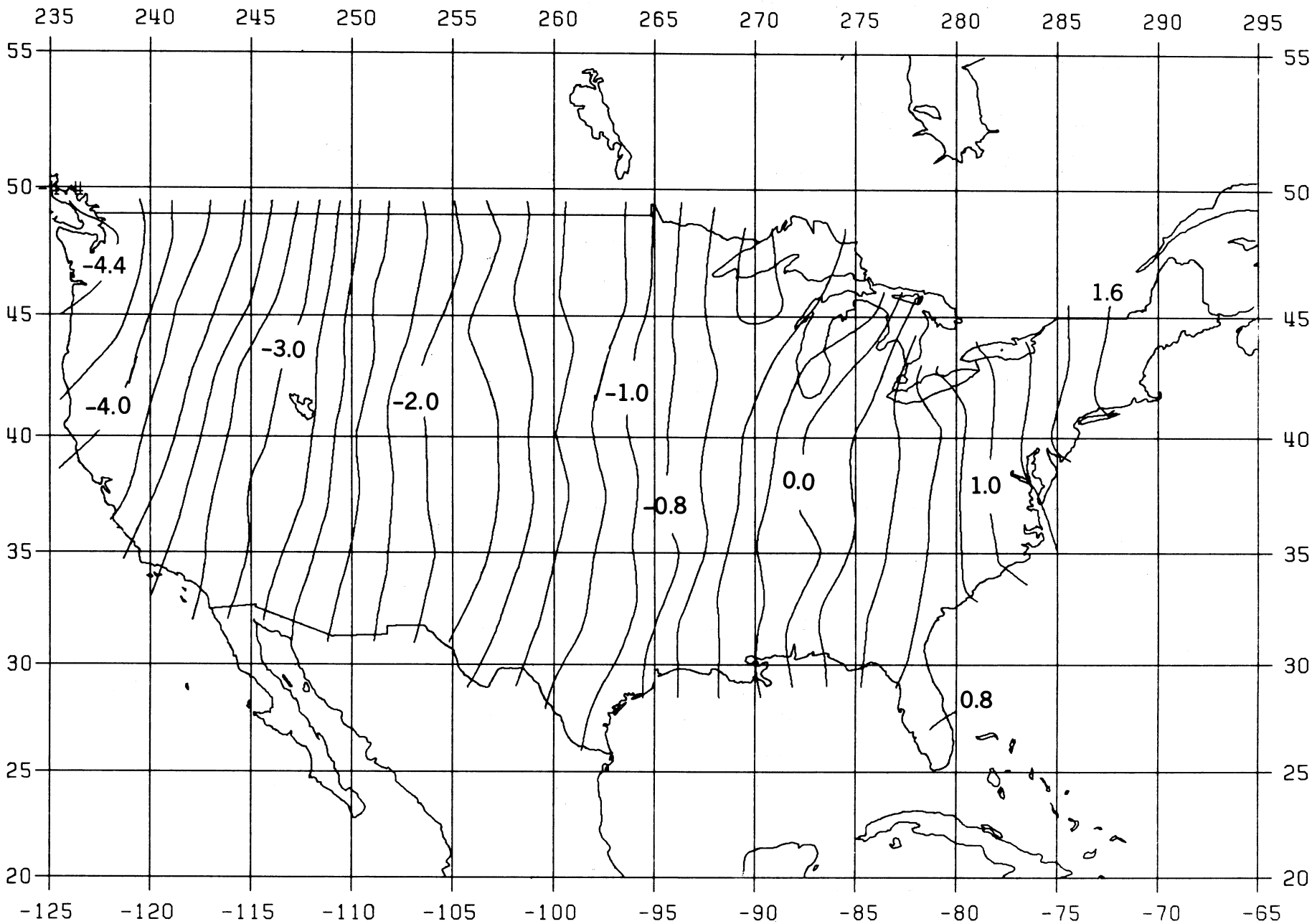

Figure 15.2. Contour Chart–Longitude Differences, WGS 84 Minus NAD 27 (CONUS; Contour Interval = 0.2 Arc Second)

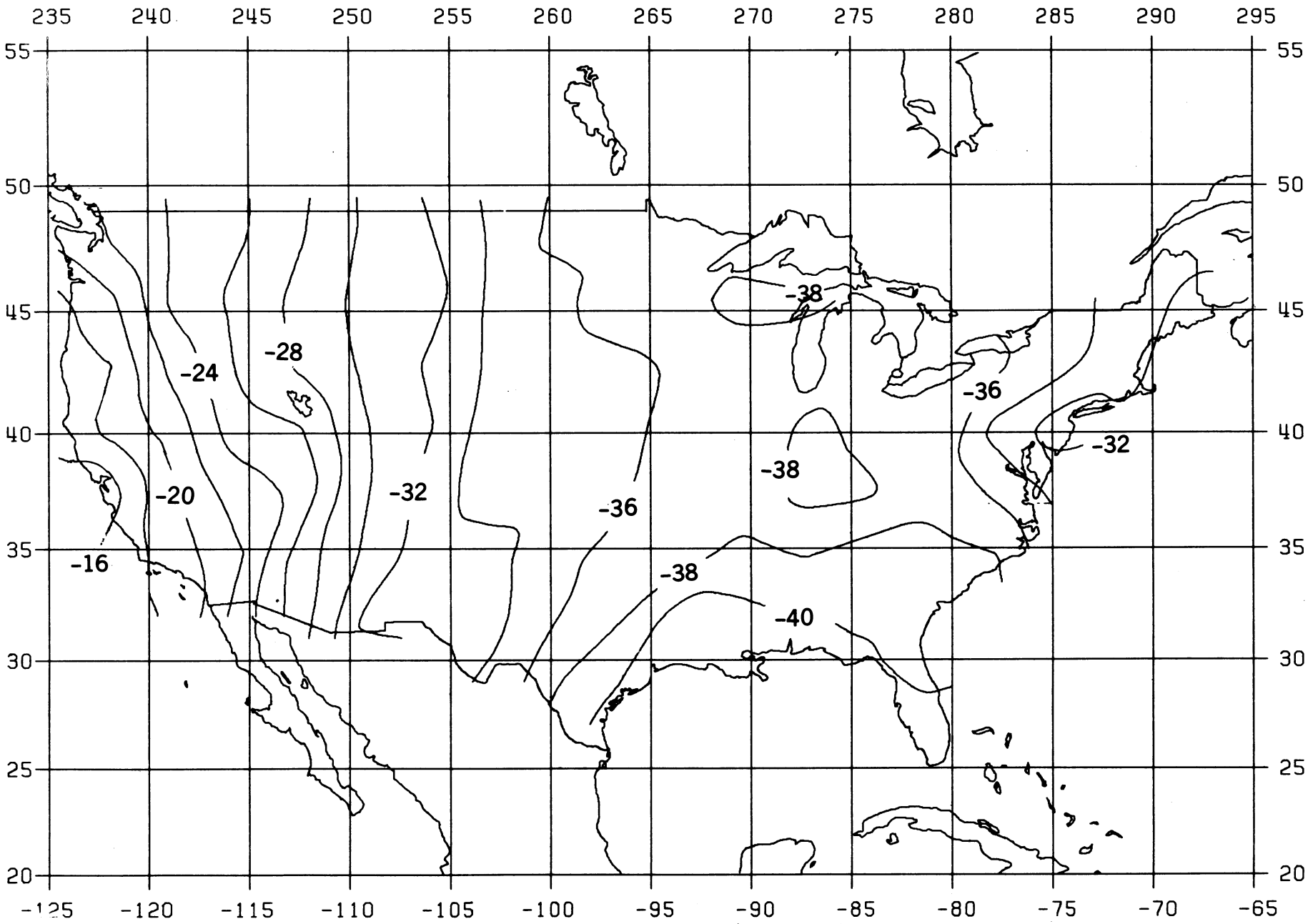

Figure 15.3. Contour Chart-Geodetic Height Differences, WGS 84 Minus NAD 27 (CONUS; Contour Interval = 2 Meters)

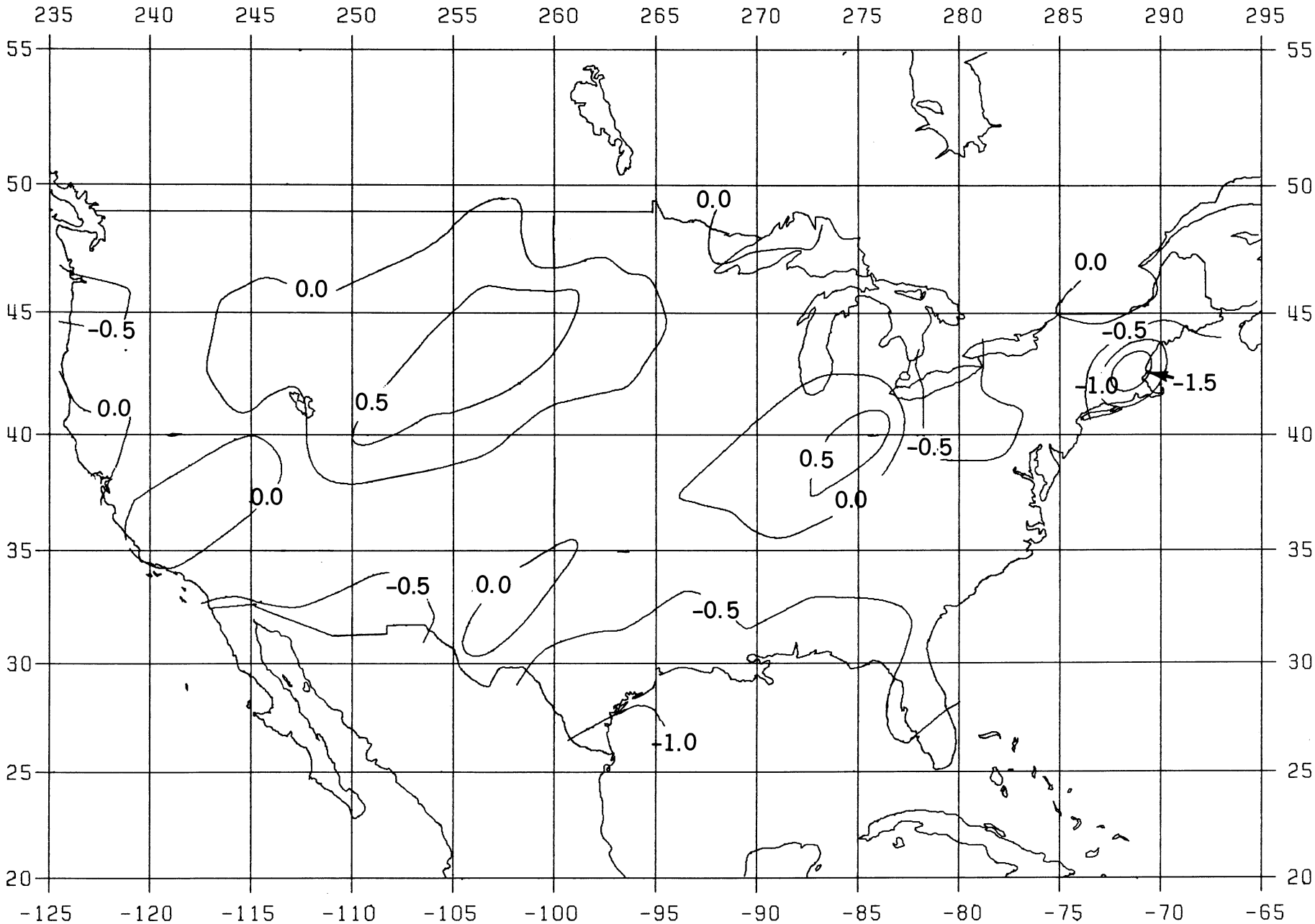

Figure 15.4. Contour Chart – Latitude Differences, WGS 84 Minus NAD 83 (CONUS; Contour Interval = 0.5 Meter)

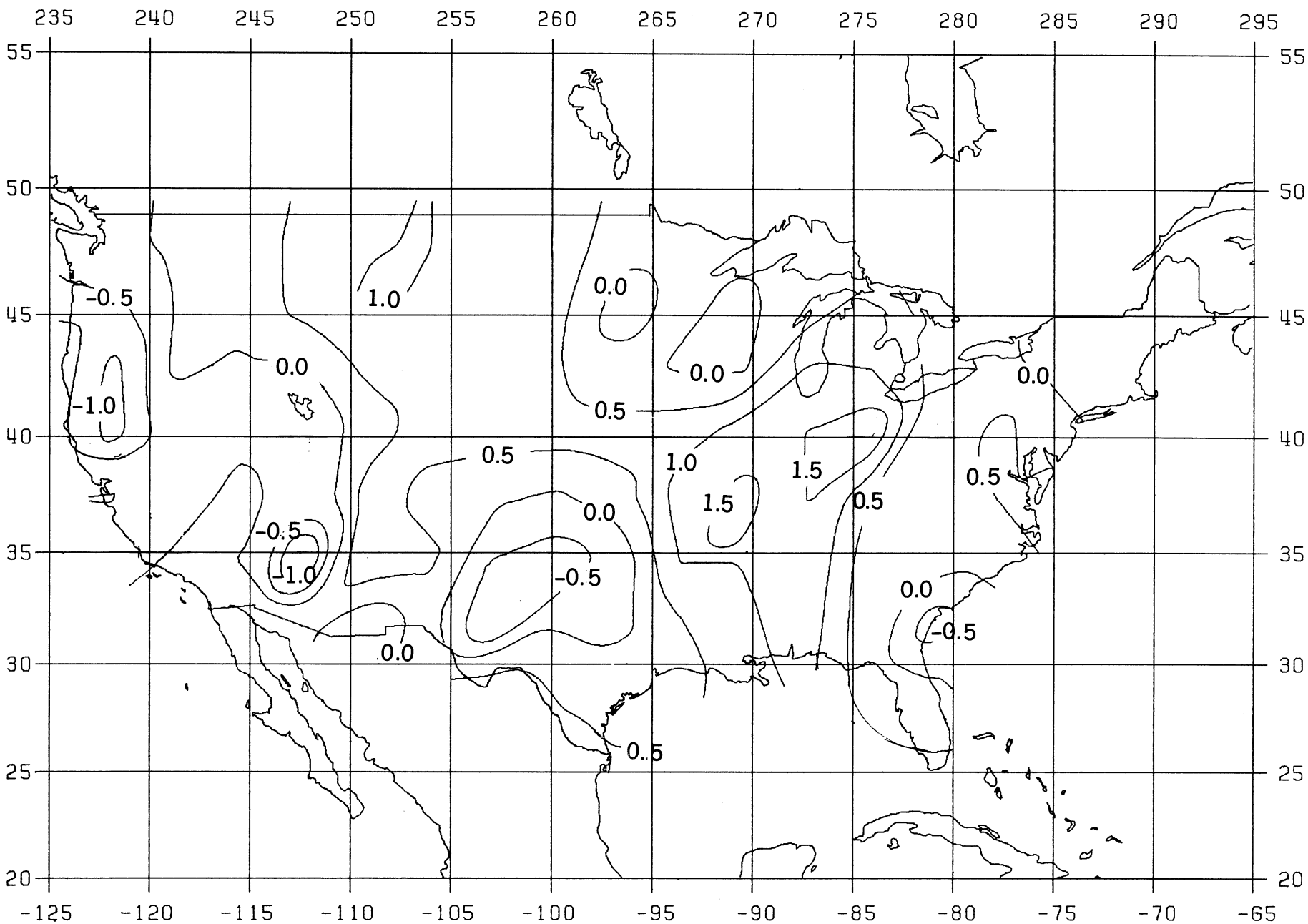

Figure 15.5. Contour Chart – Longitude Differences, WGS 84 Minus NAD 83 (CONUS; Contour Interval = 0.5 Meter)

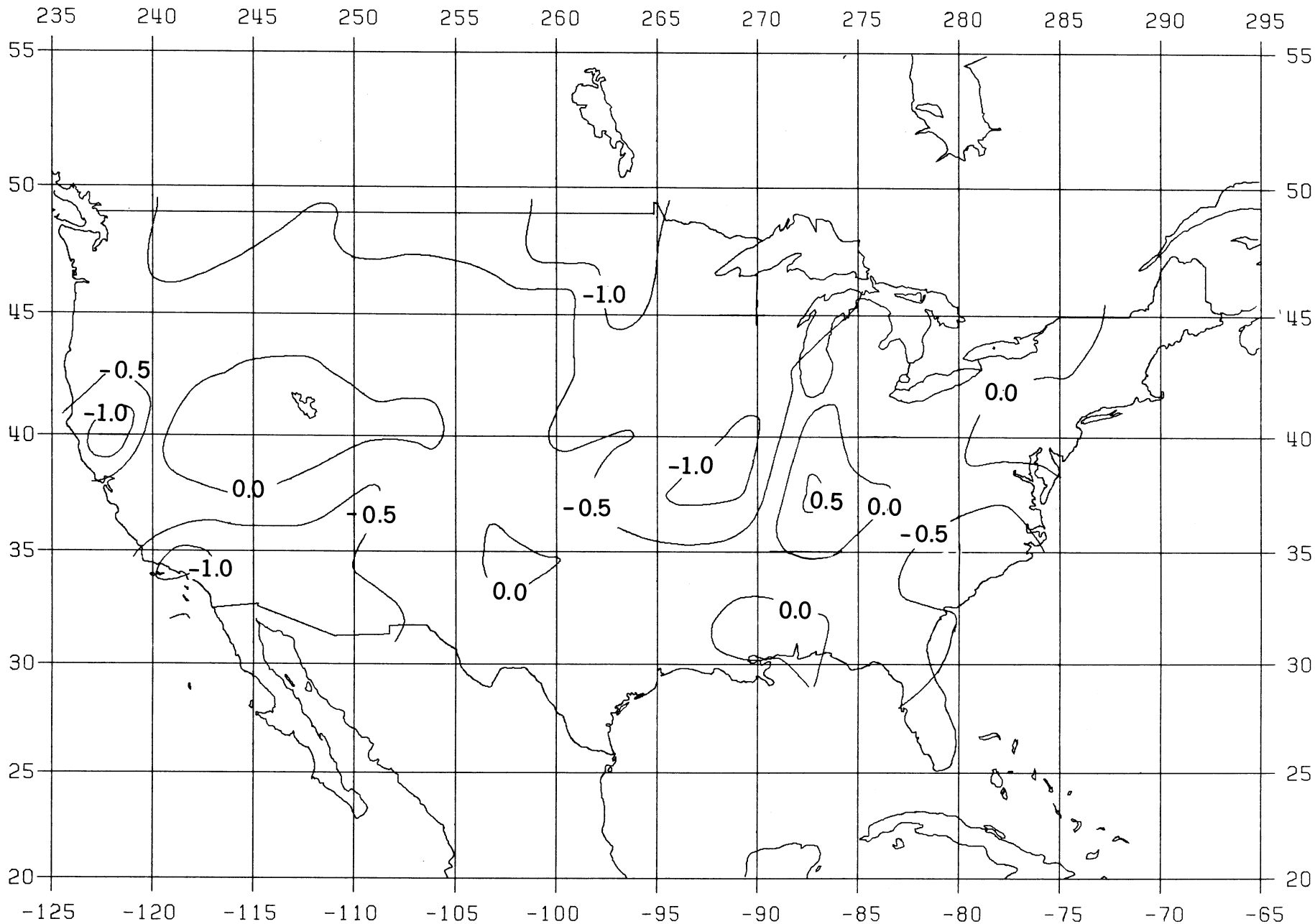

Figure 15.6. Contour Chart - Geodetic Height Differences, WGS 84 Minus NAD 83 (CONUS; Contour Interval = 0.5 Meter)

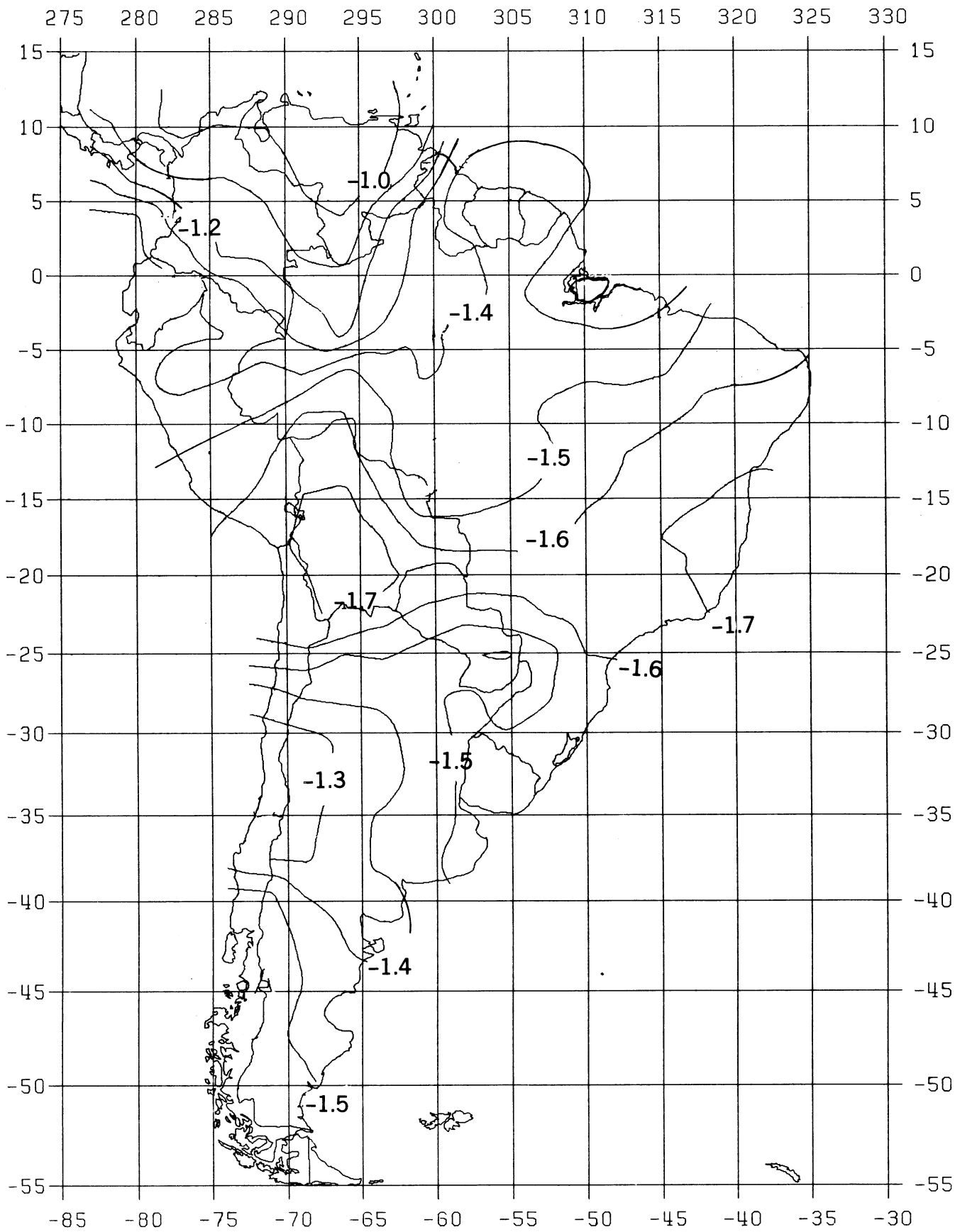

Figure 15.7 Contour Chart – Latitude Differences, WGS 84 Minus SAD 69 (Contour Interval = 0.1 Arc Second)

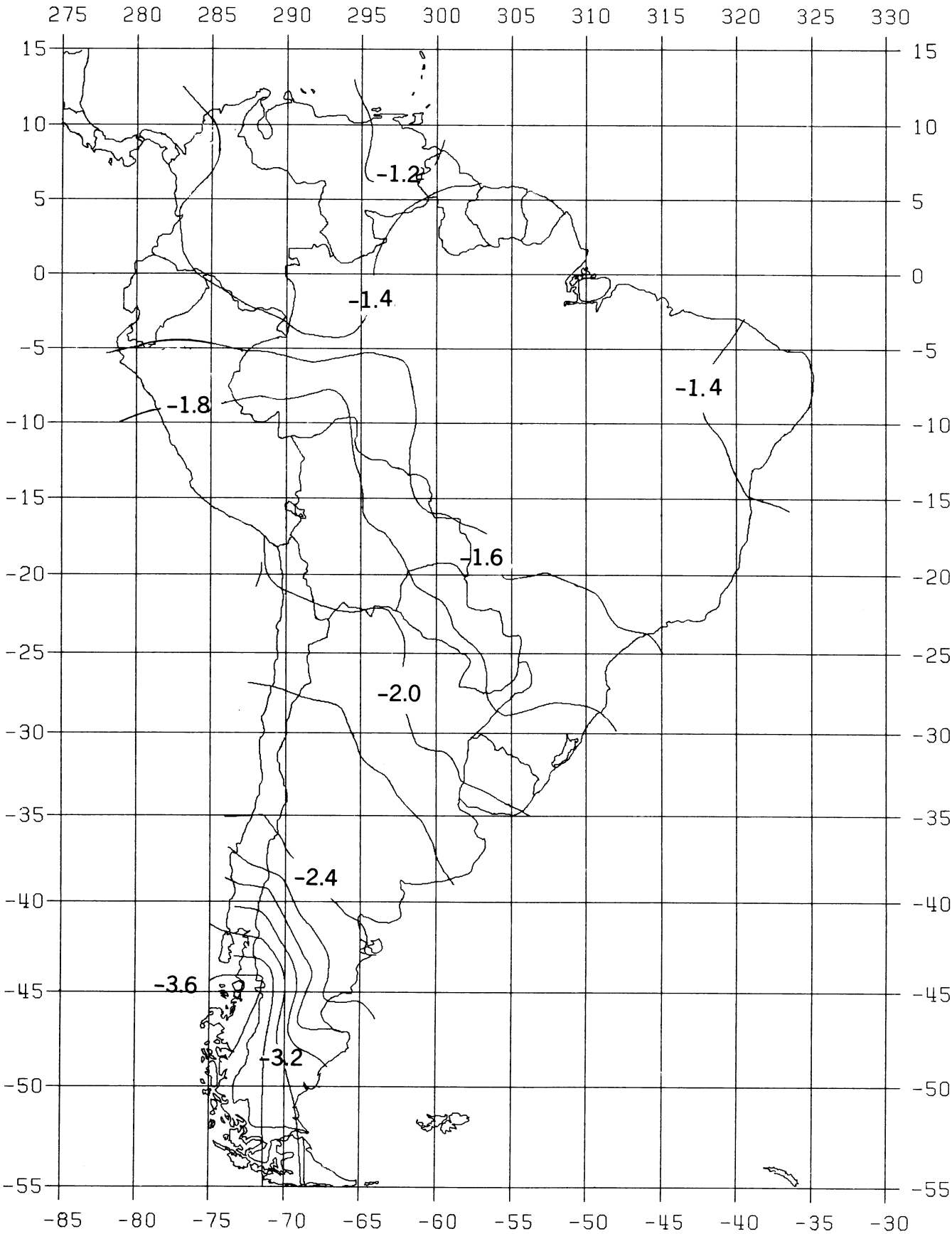

Figure 15.8. Contour Chart – Longitude Differences, WGS 84 Minus SAD 69 (Contour Interval = 0.2 Arc Second)

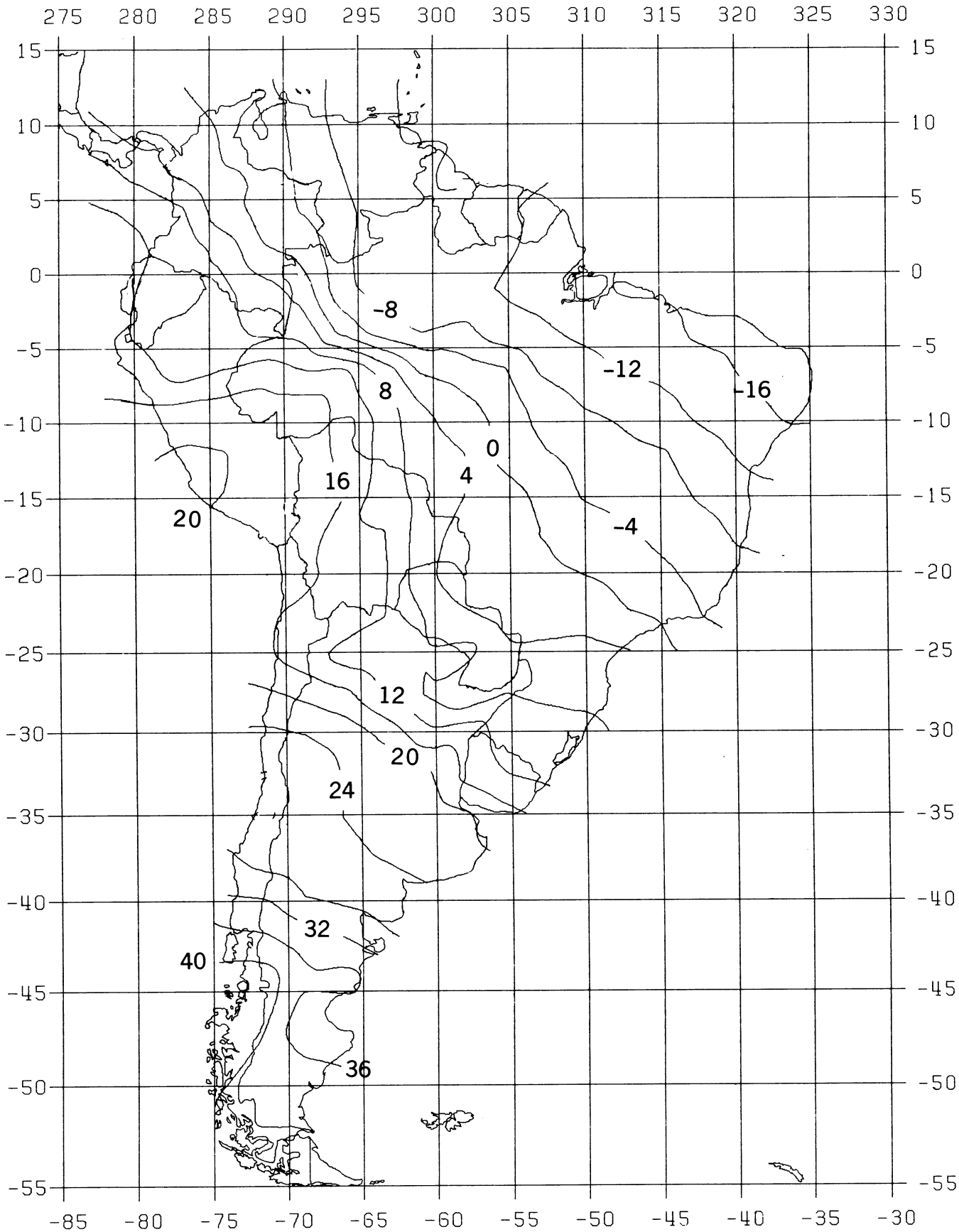

Figure 15.9. Contour Chart - Geodetic Height Differences, WGS 84 Minus SAD 69 (Contour Interval = 4 Meters)

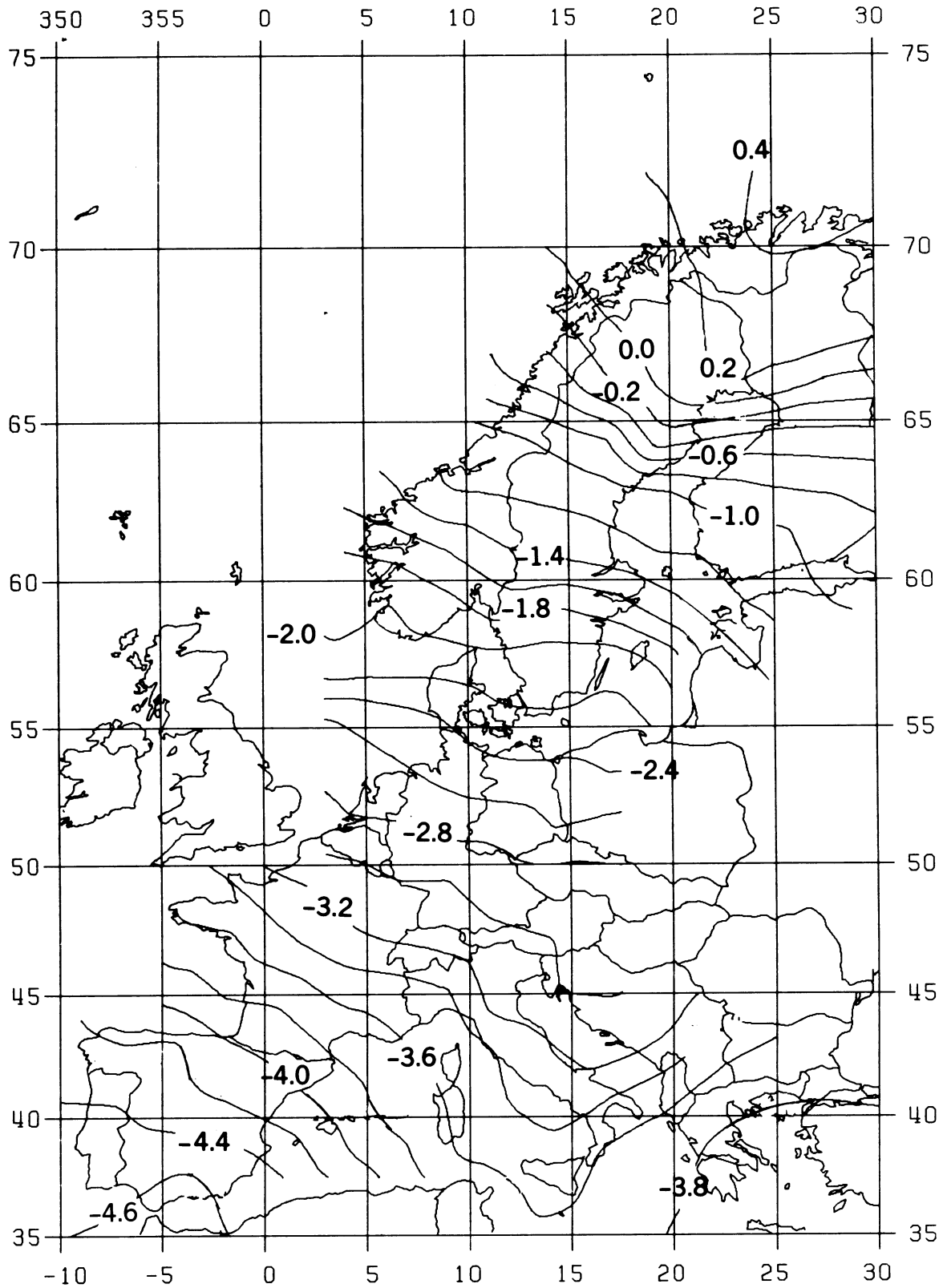

Figure 15.10. Contour Chart - Latitude Differences, WGS 84 Minus ED 50 (Western Europe; Contour Interval = 0.2 Arc Second)

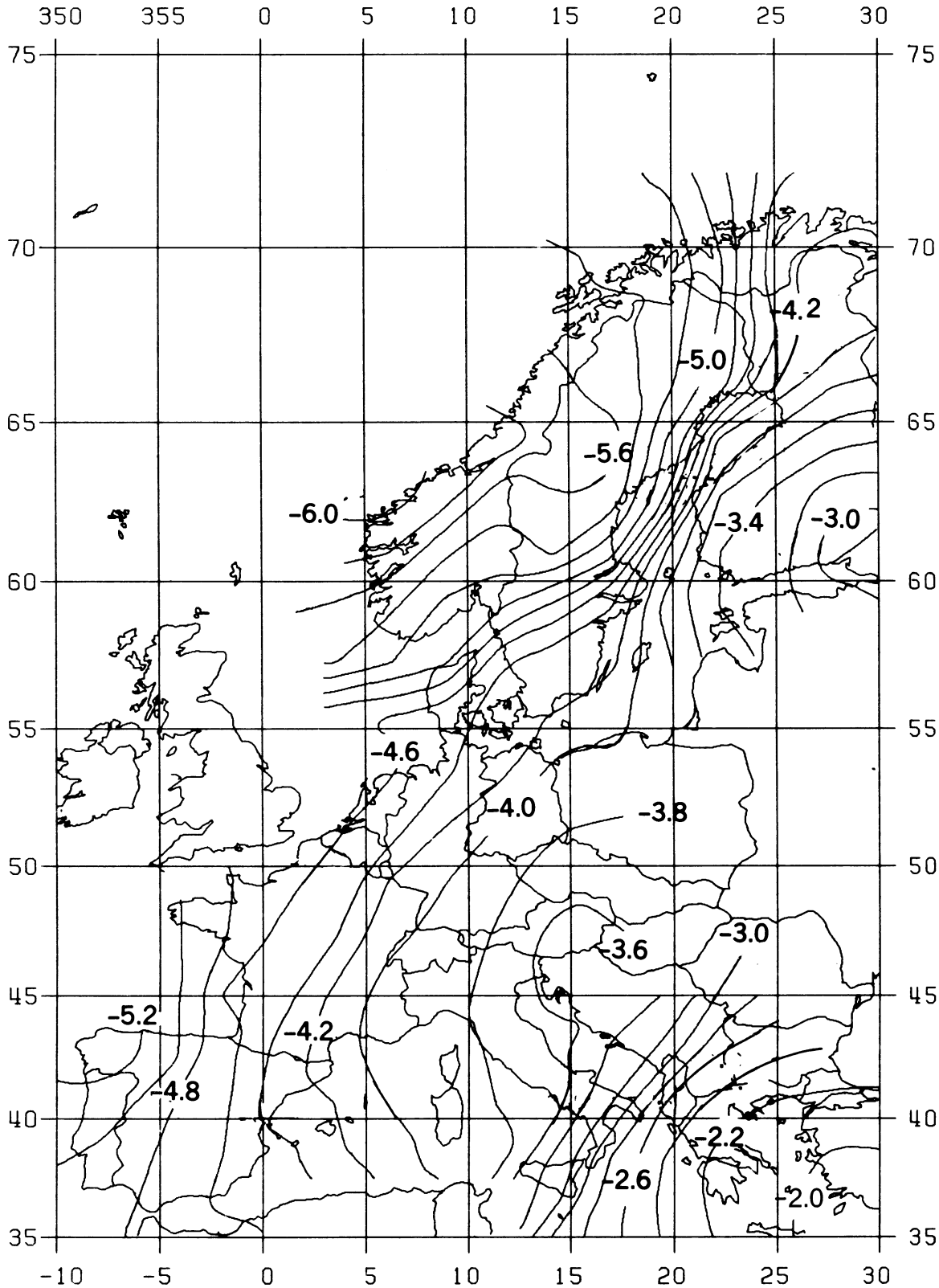

Figure 15.11. Contour Chart–Longitude Differences, WGS 84 Minus ED 50 (Western Europe; Contour Interval = 0.2 Arc Second)

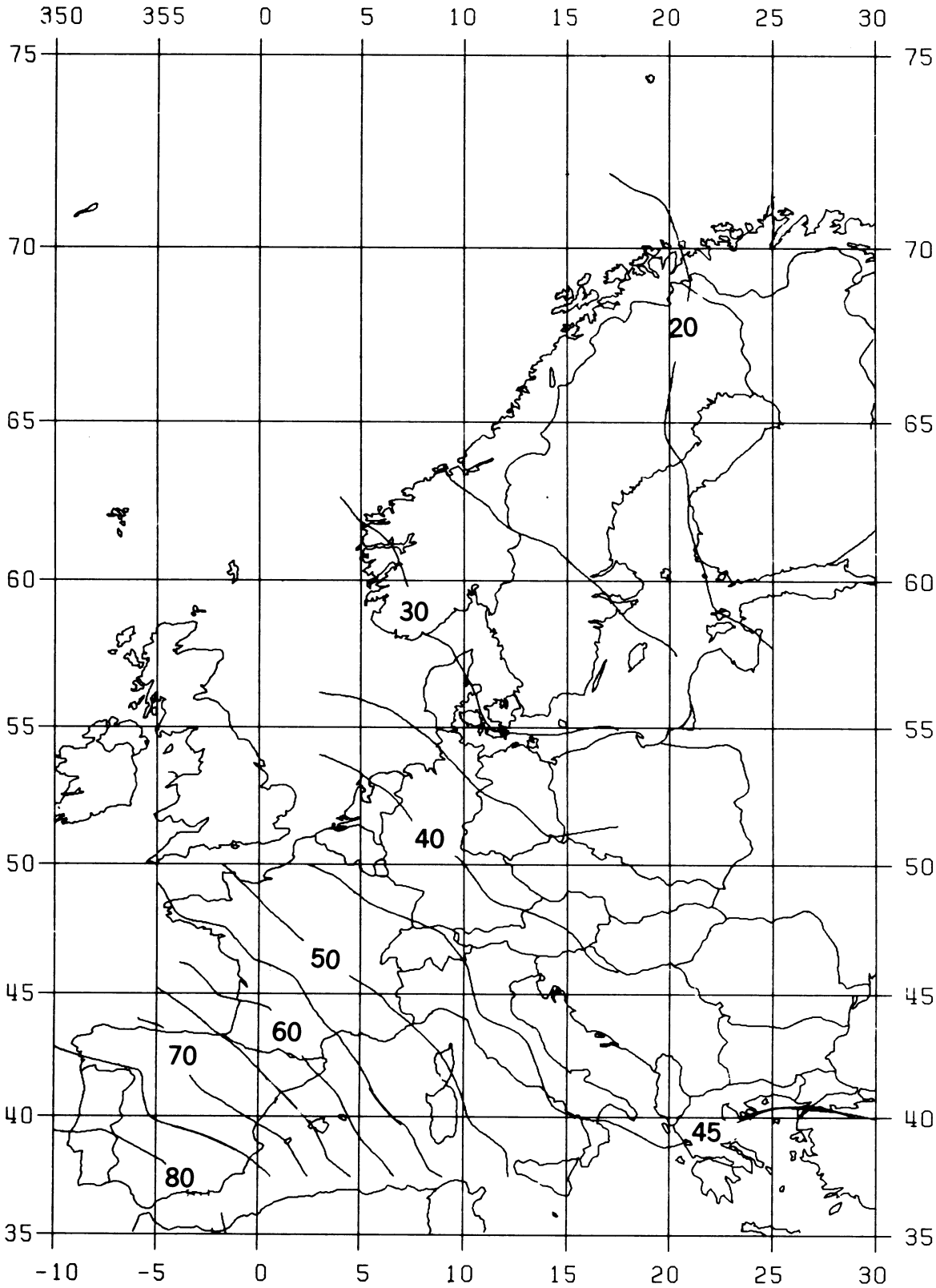

Figure 15.12. Contour Chart–Geodetic Height Differences, WGS 84 Minus ED 50 (Western Europe; Contour Interval = 5 Meters)

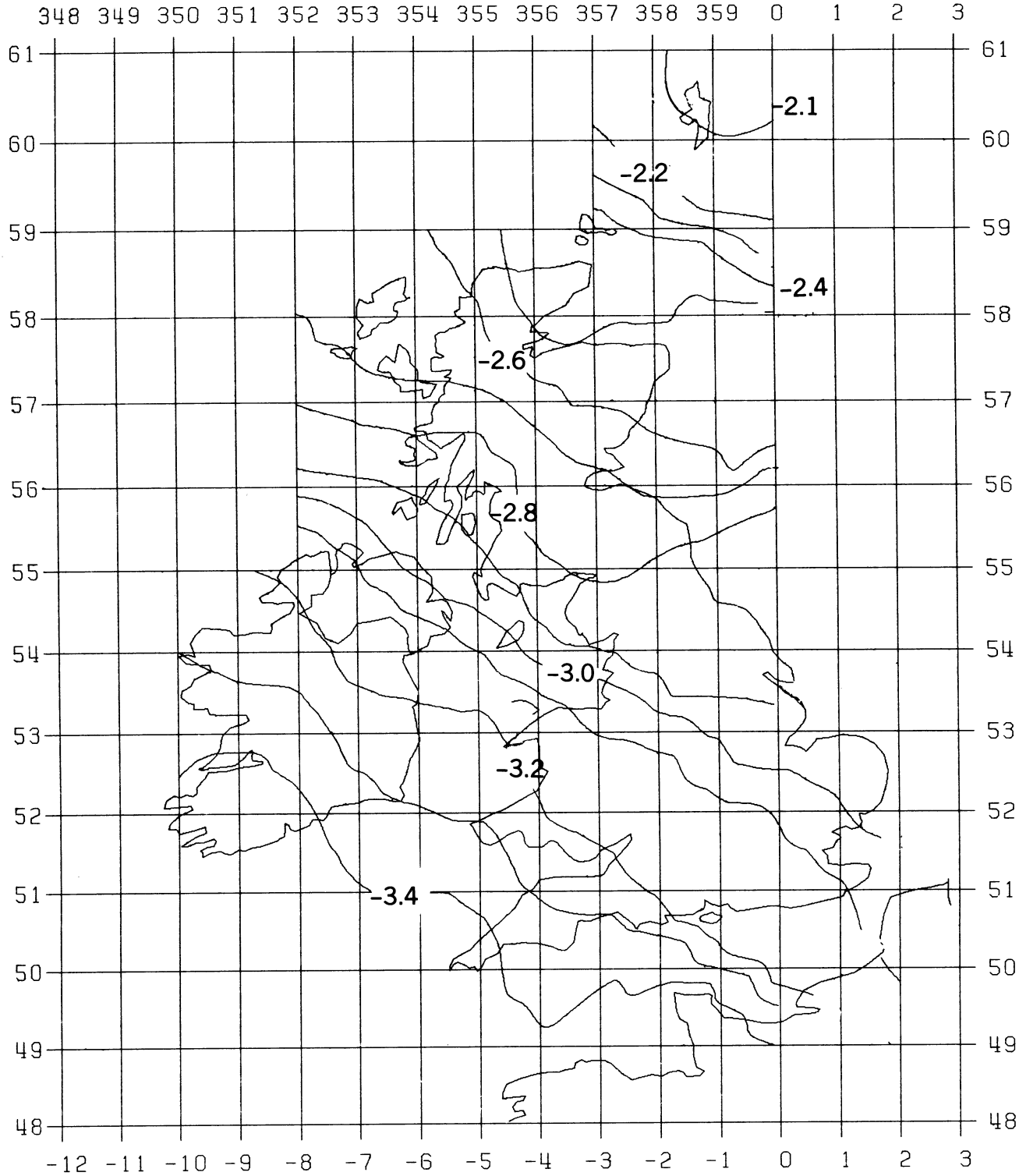

Figure 15.13. Contour Chart - Latitude Differences, WGS 84 Minus ED 50 (UK/Ireland; Contour Interval = 0.1 Arc Second)

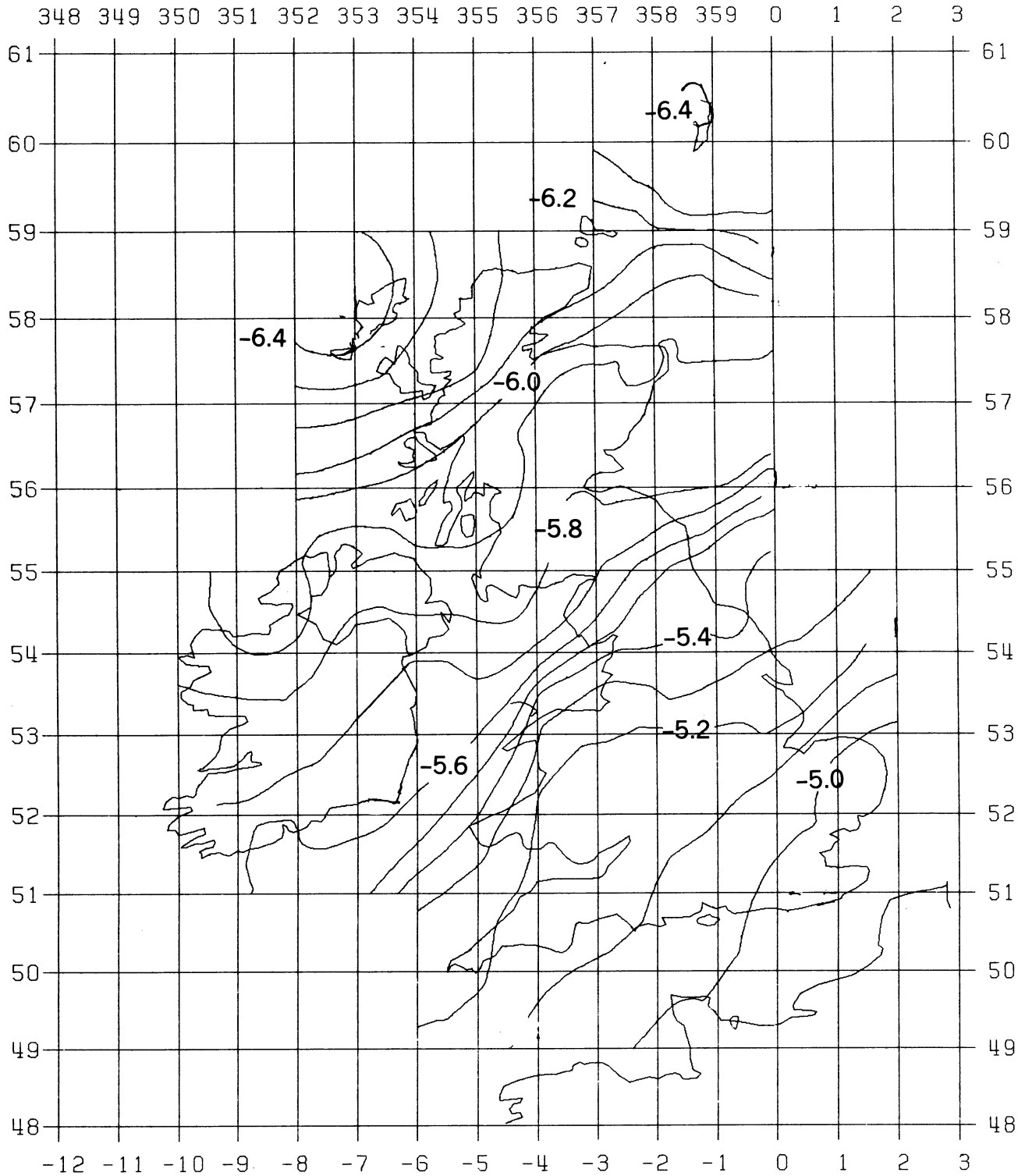

Figure 15.14. Contour Chart - Longitude Differences, WGS 84 Minus ED 50 (UK/Ireland; Contour Interval = 0.1 Arc Second)

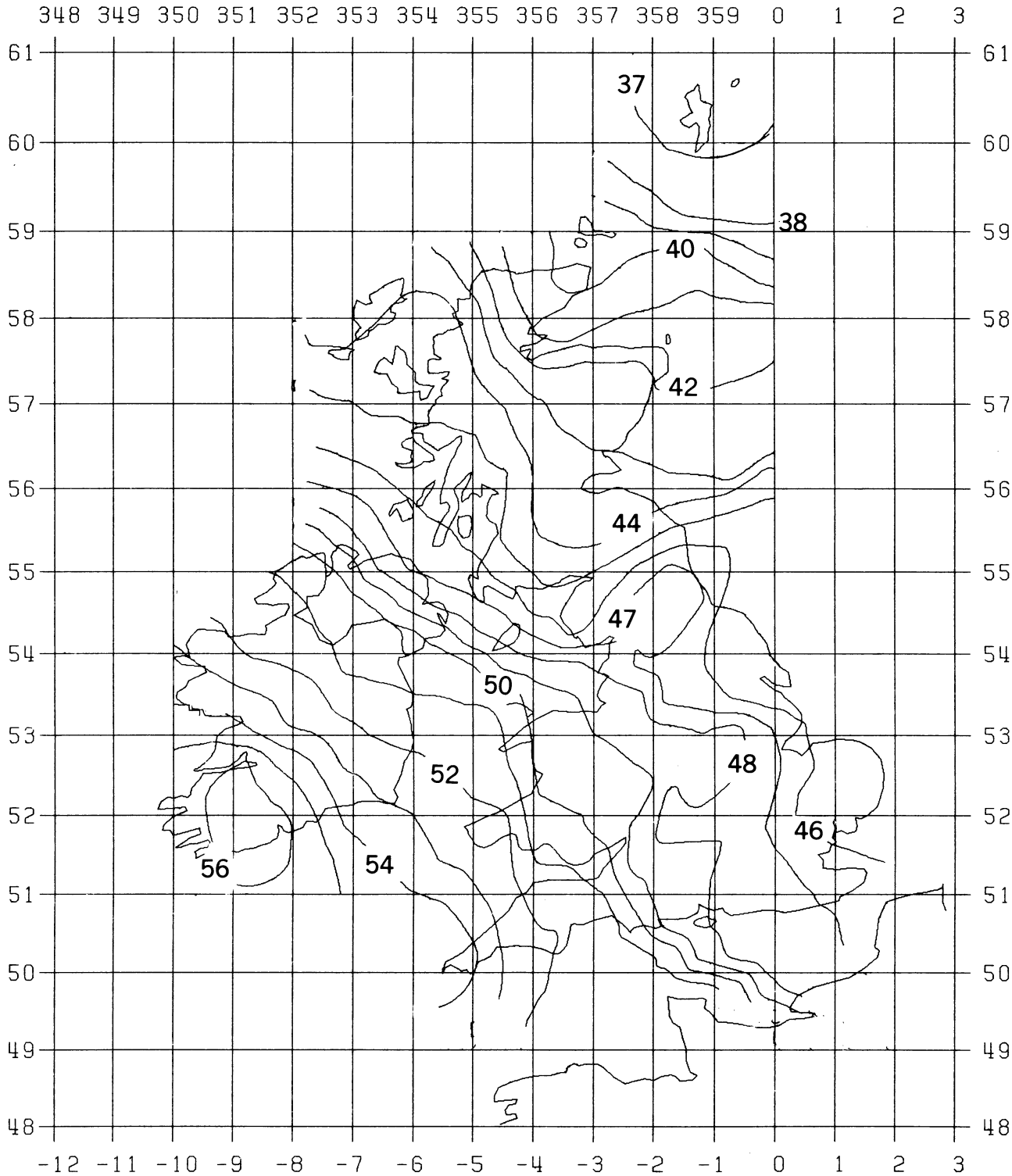

Figure 15.15. Contour Chart - Geodetic Height Differences, WGS 84 Minus ED 50 (UK/Ireland; Contour Interval = 1 Meter)

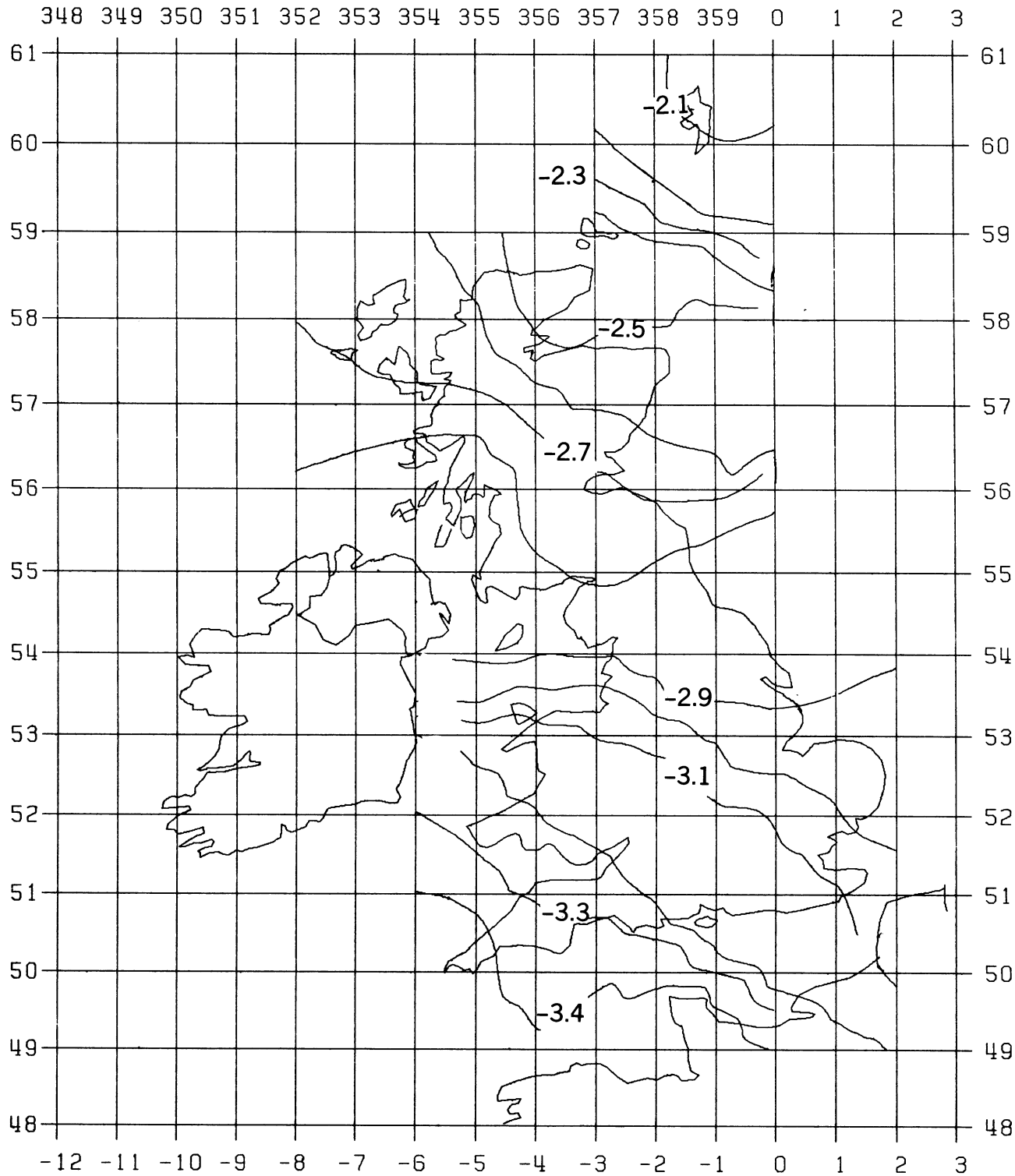

Figure 15.16. Contour Chart – Latitude Differences, WGS 84 Minus ED 50 (UK Only; Contour Interval = 0.1 Arc Second)

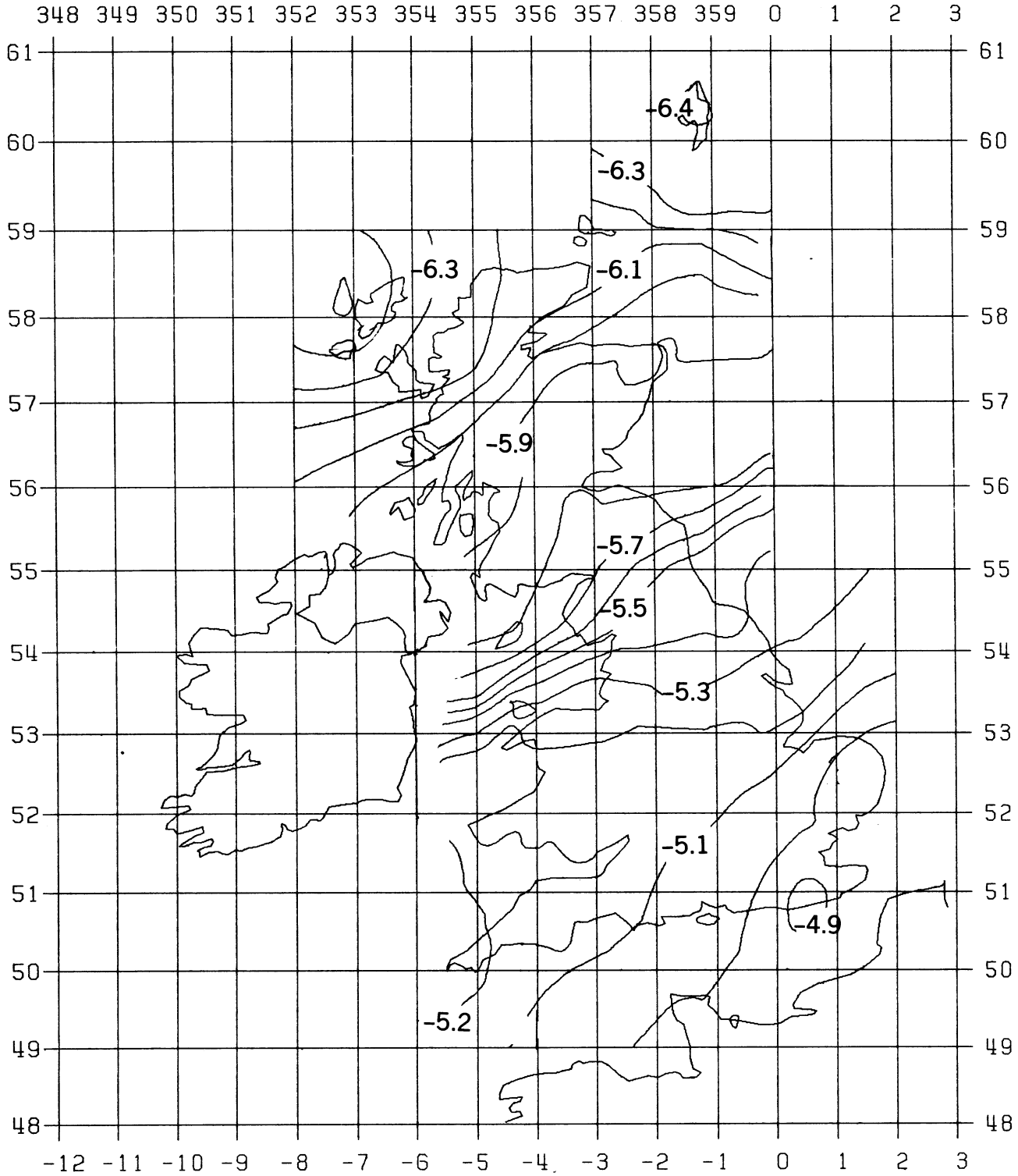

Figure 15.17. Contour Chart – Longitude Differences, WGS 84 Minus ED 50
(UK Only; Contour Interval = 0.1 Arc Second)

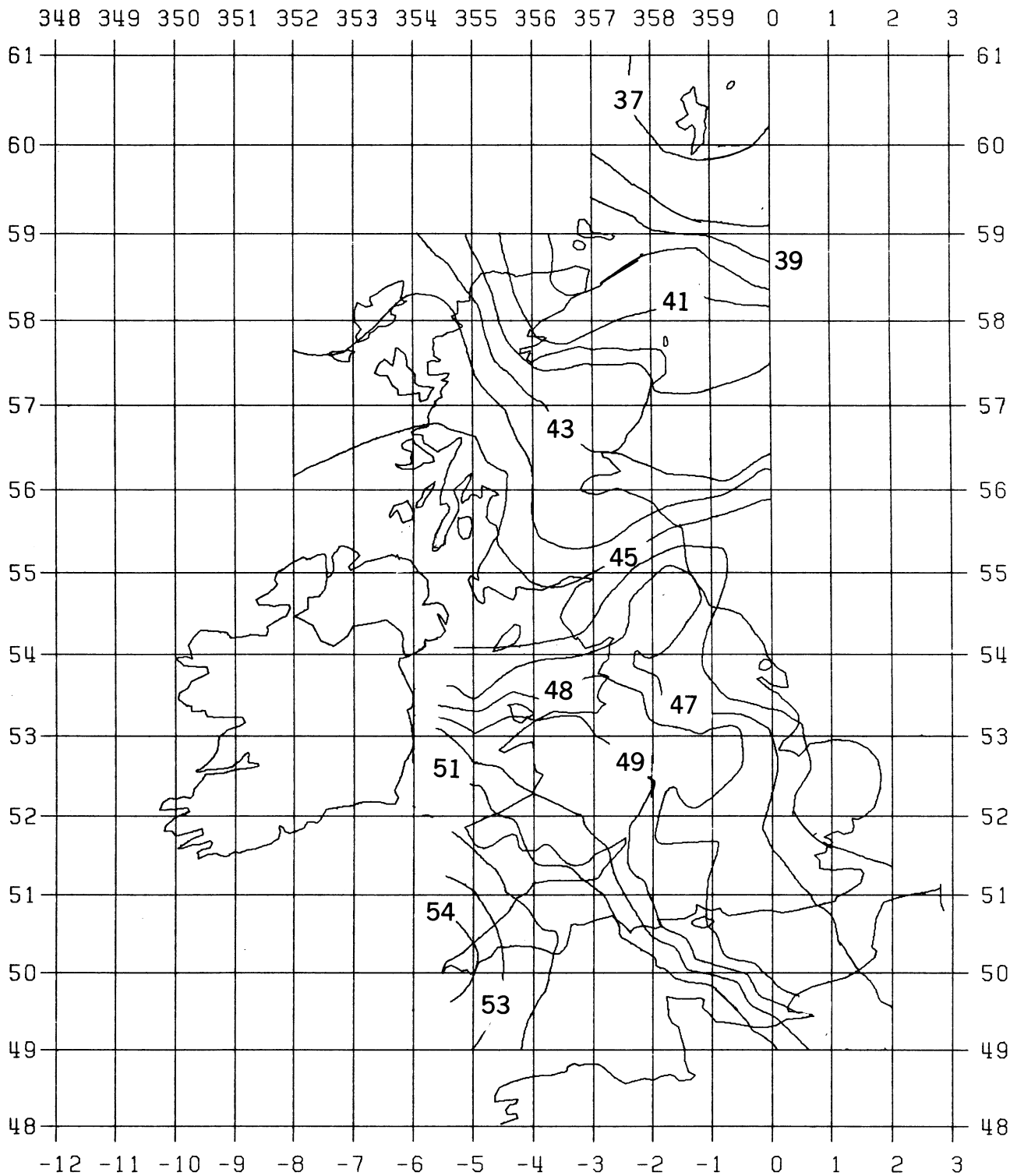

Figure 15.18. Contour Chart - Geodetic Height Differences, WGS 84 Minus ED 50
(UK Only; Contour Interval = 1 Meter)

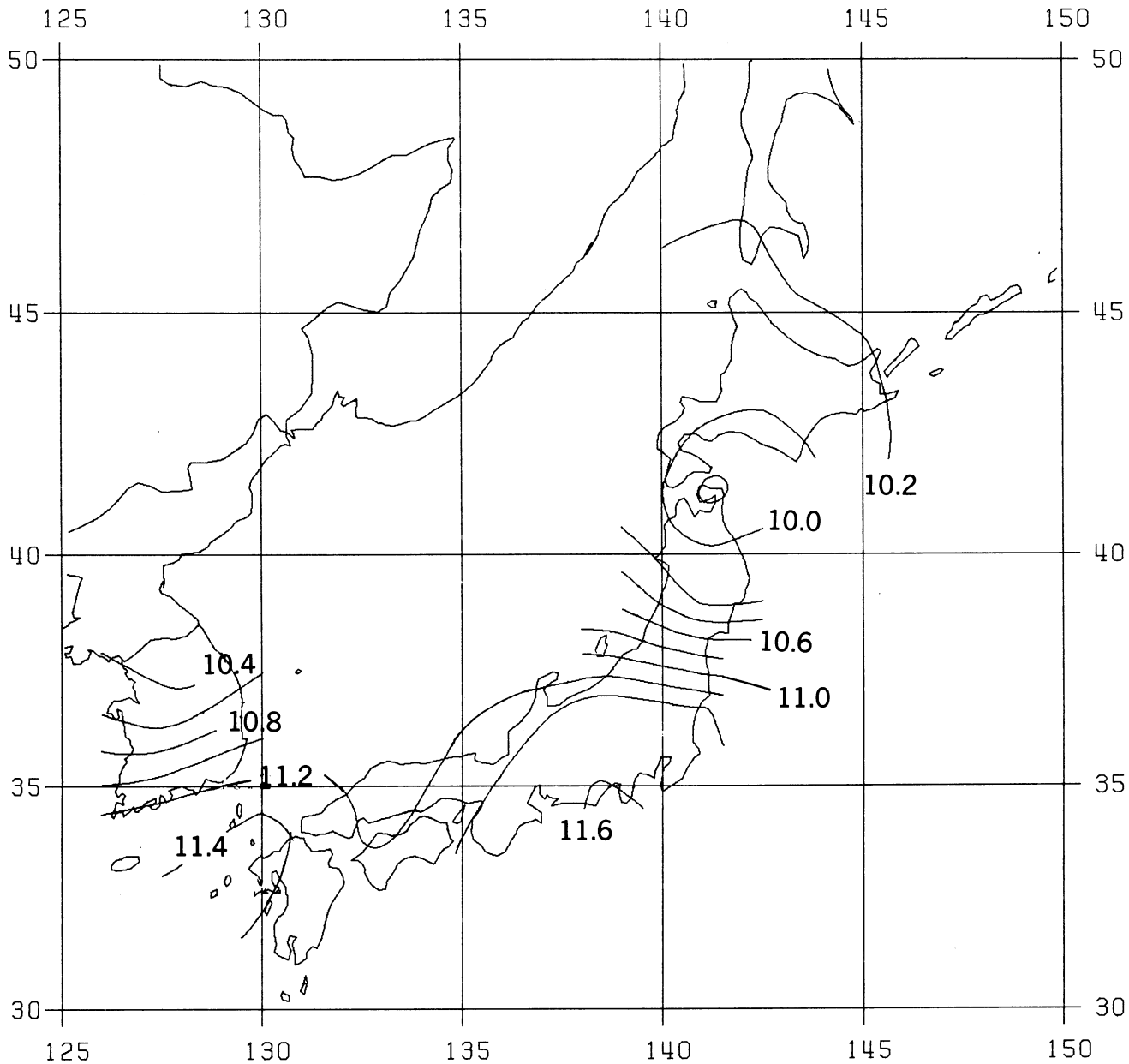

Figure 15.19. Contour Chart – Latitude Differences, WGS 84 Minus TD (Contour Interval = 0.2 Arc Second)

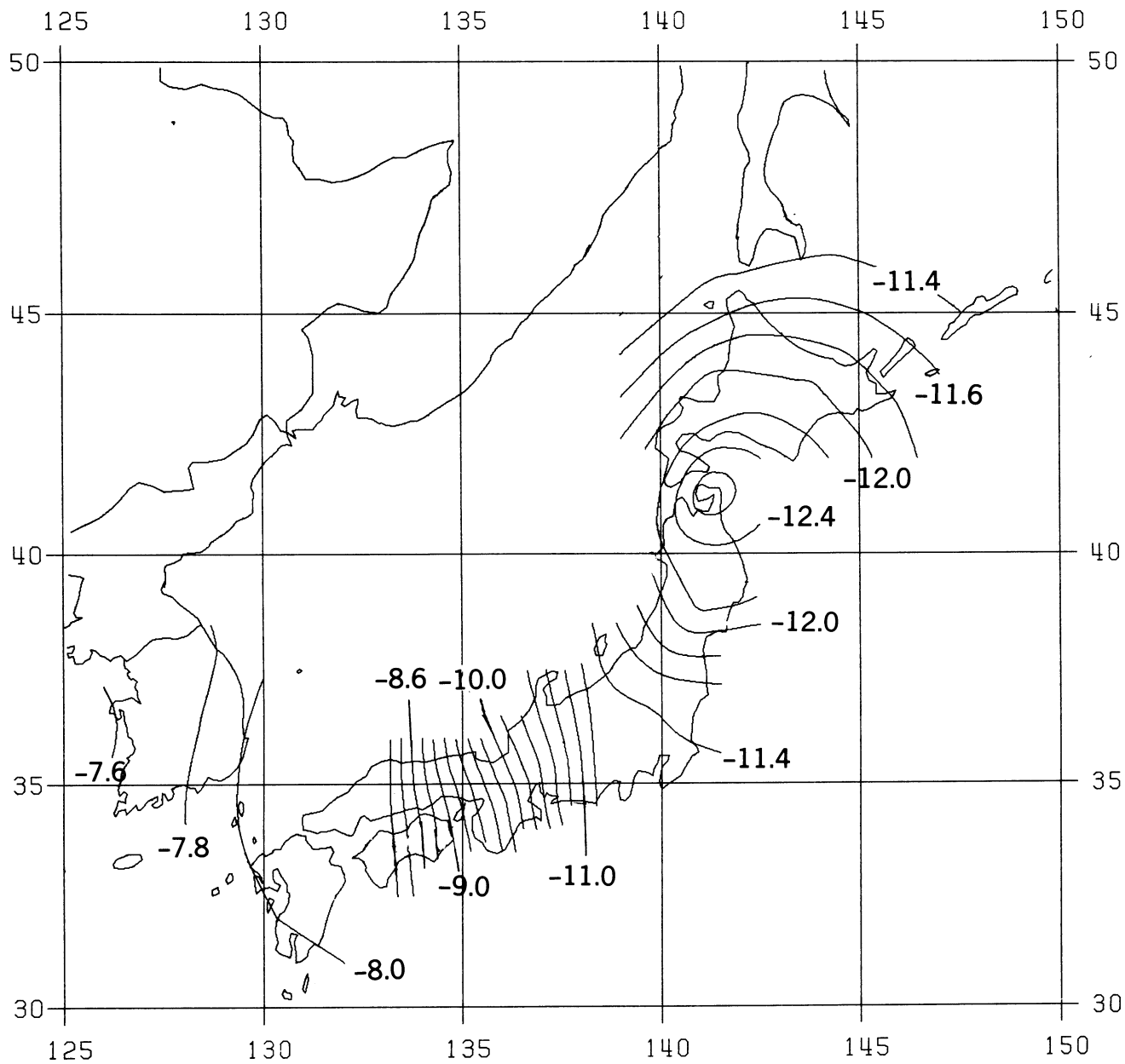

Figure 15.20. Contour Chart – Longitude Differences, WGS 84 Minus TD (Contour Interval = 0.2 Arc Second)

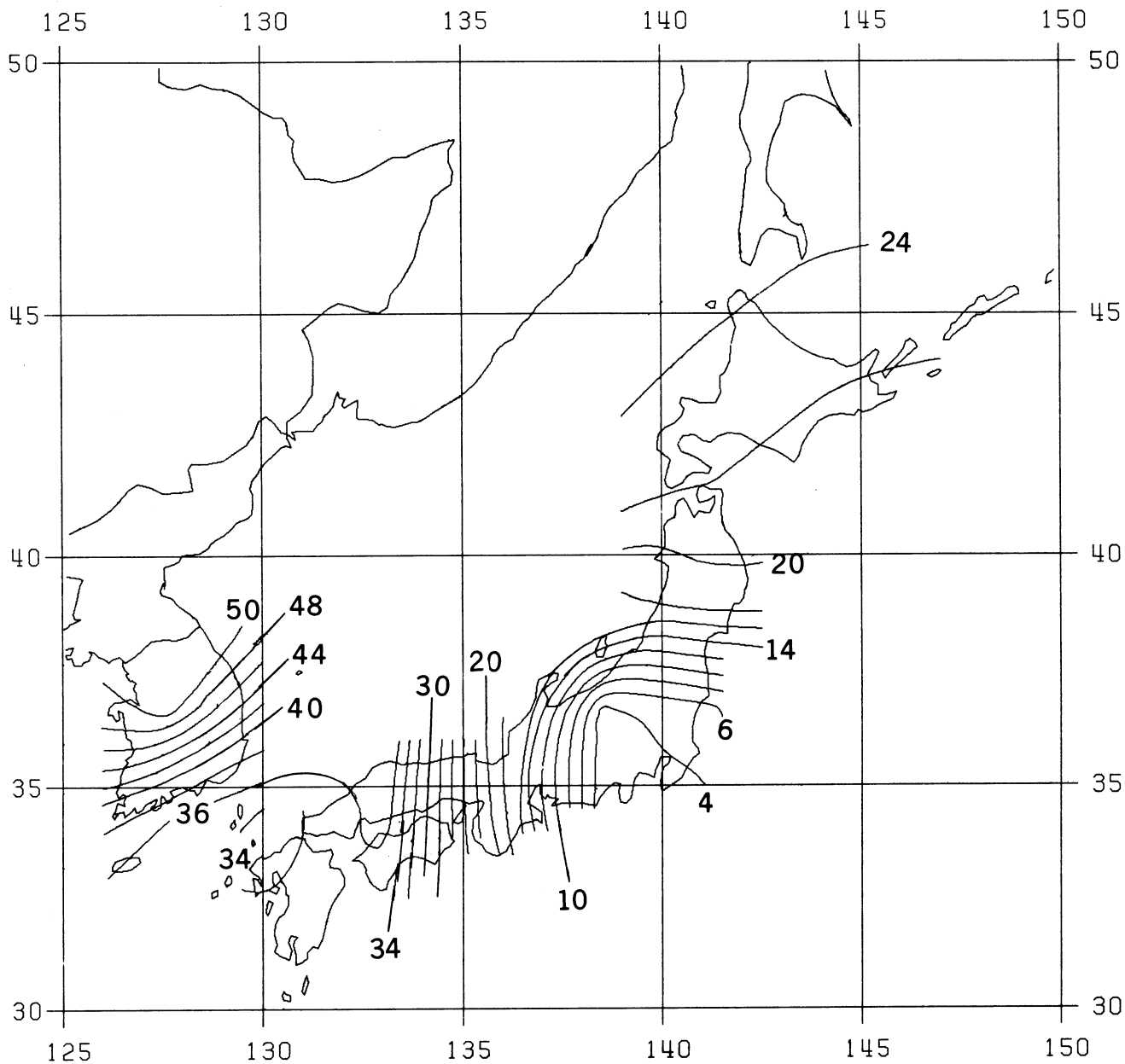

Figure 15.21. Contour Chart – Geodetic Height Differences, WGS 84 Minus TD (Contour Interval = 2 Meters)

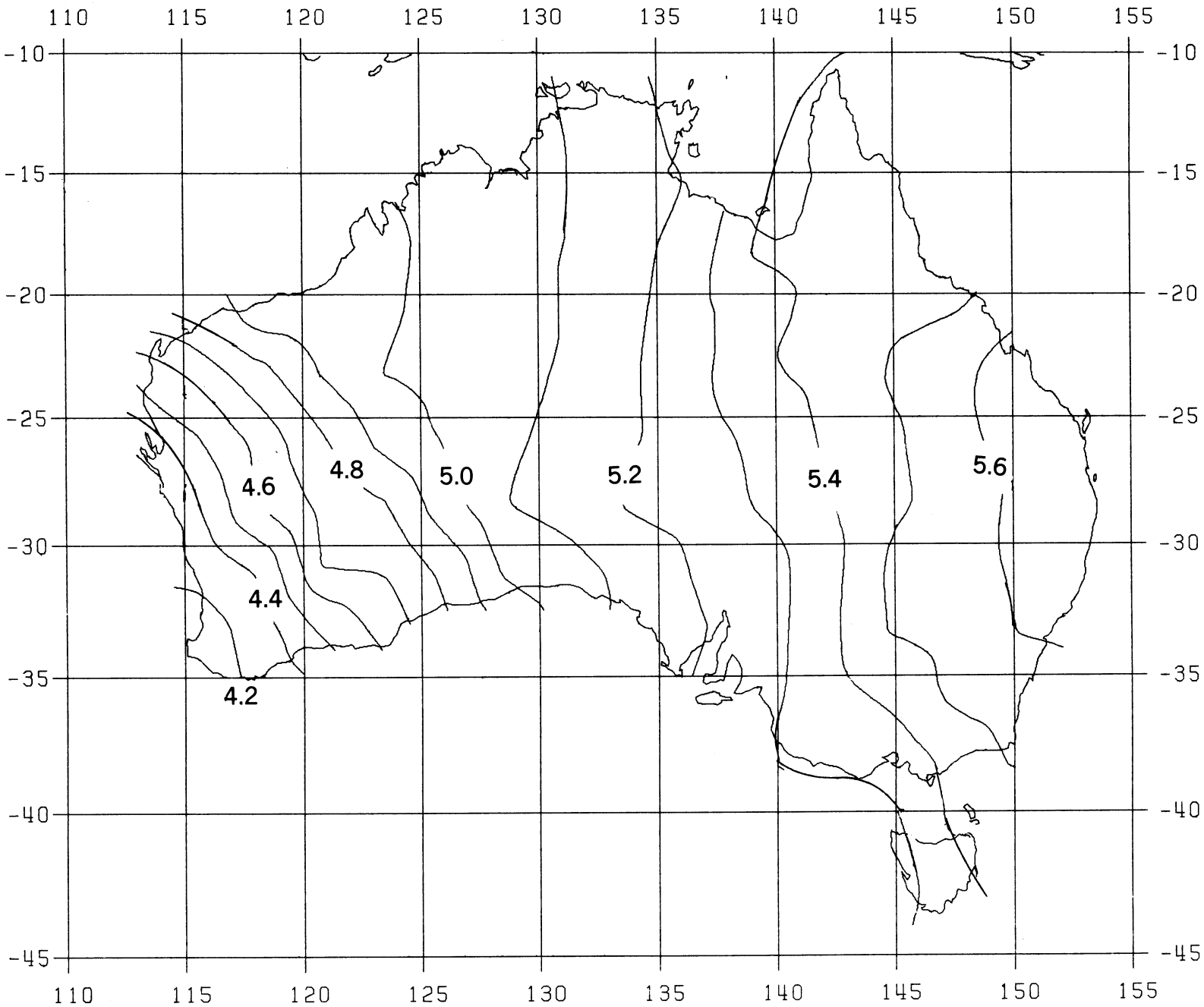

Figure 15.22. Contour Chart – Latitude Differences, WGS 84 Minus AGD 66 (Contour Interval = 0.1 Arc Second)

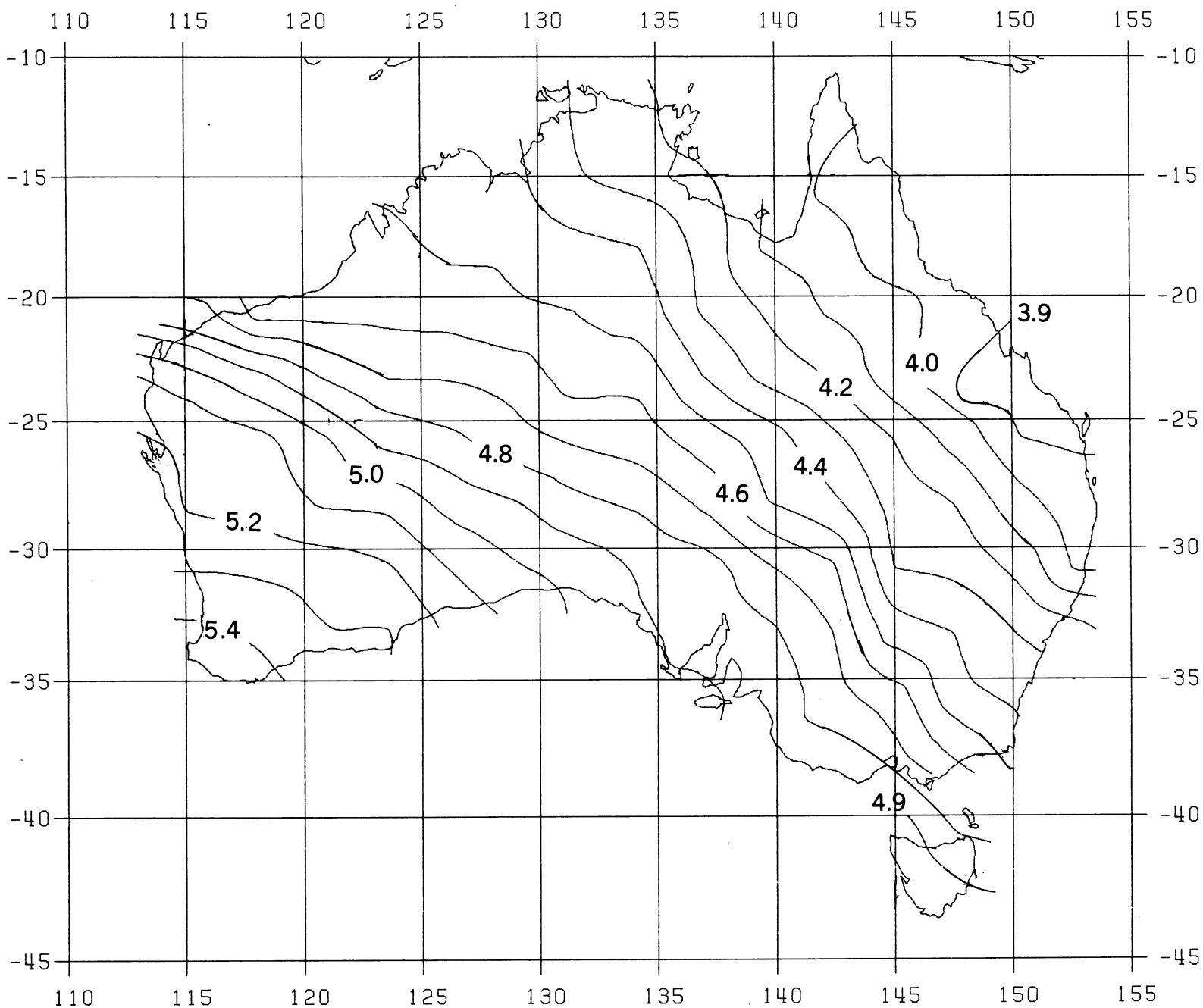

Figure 15.23. Contour Chart – Longitude Differences, WGS 84 Minus AGD 66 (Contour Interval = 0.1 Arc Second)

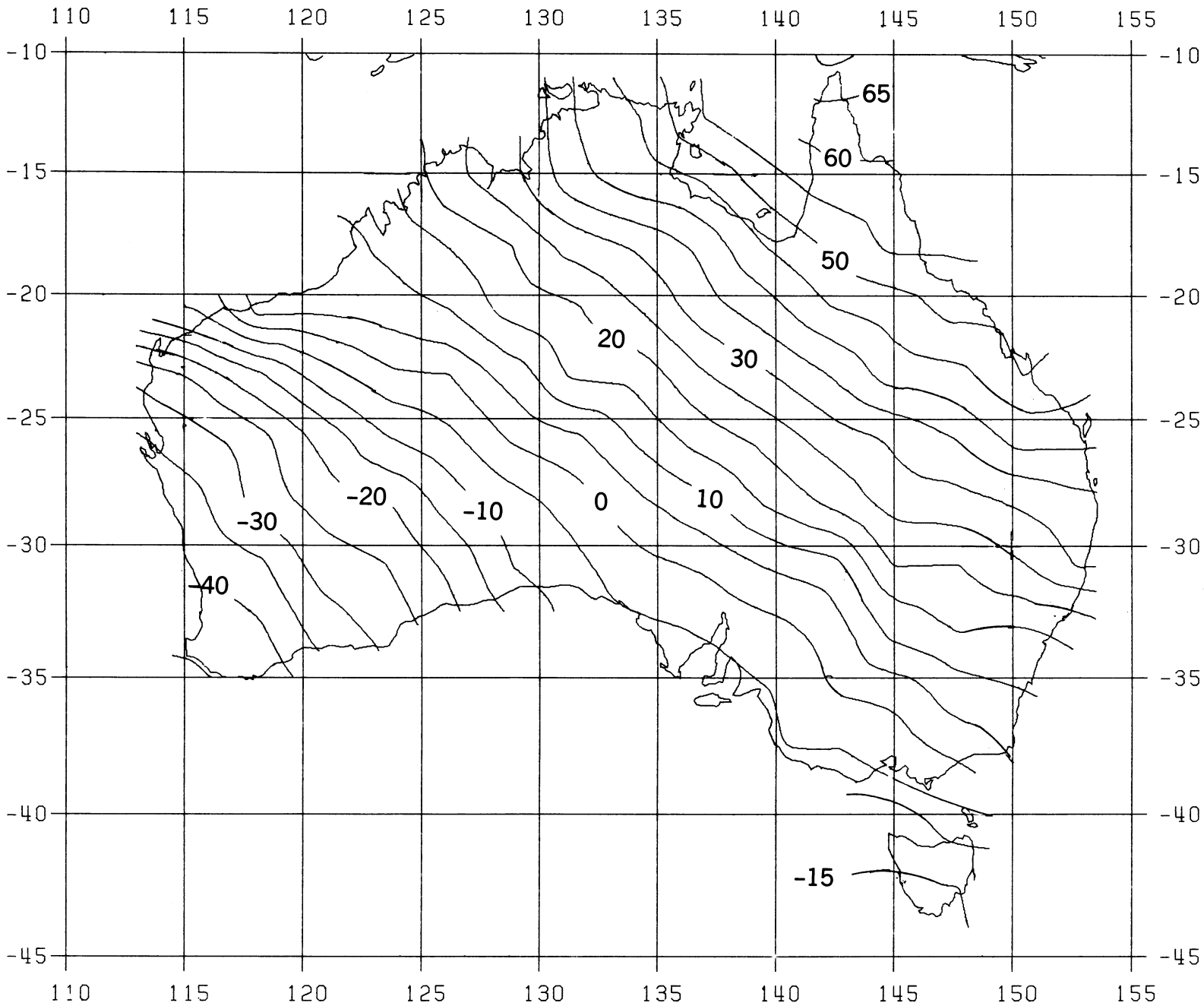

Figure 15.24. Contour Chart - Geodetic Height Differences, WGS 84 Minus AGD 66 (Contour Interval = 5 Meters)

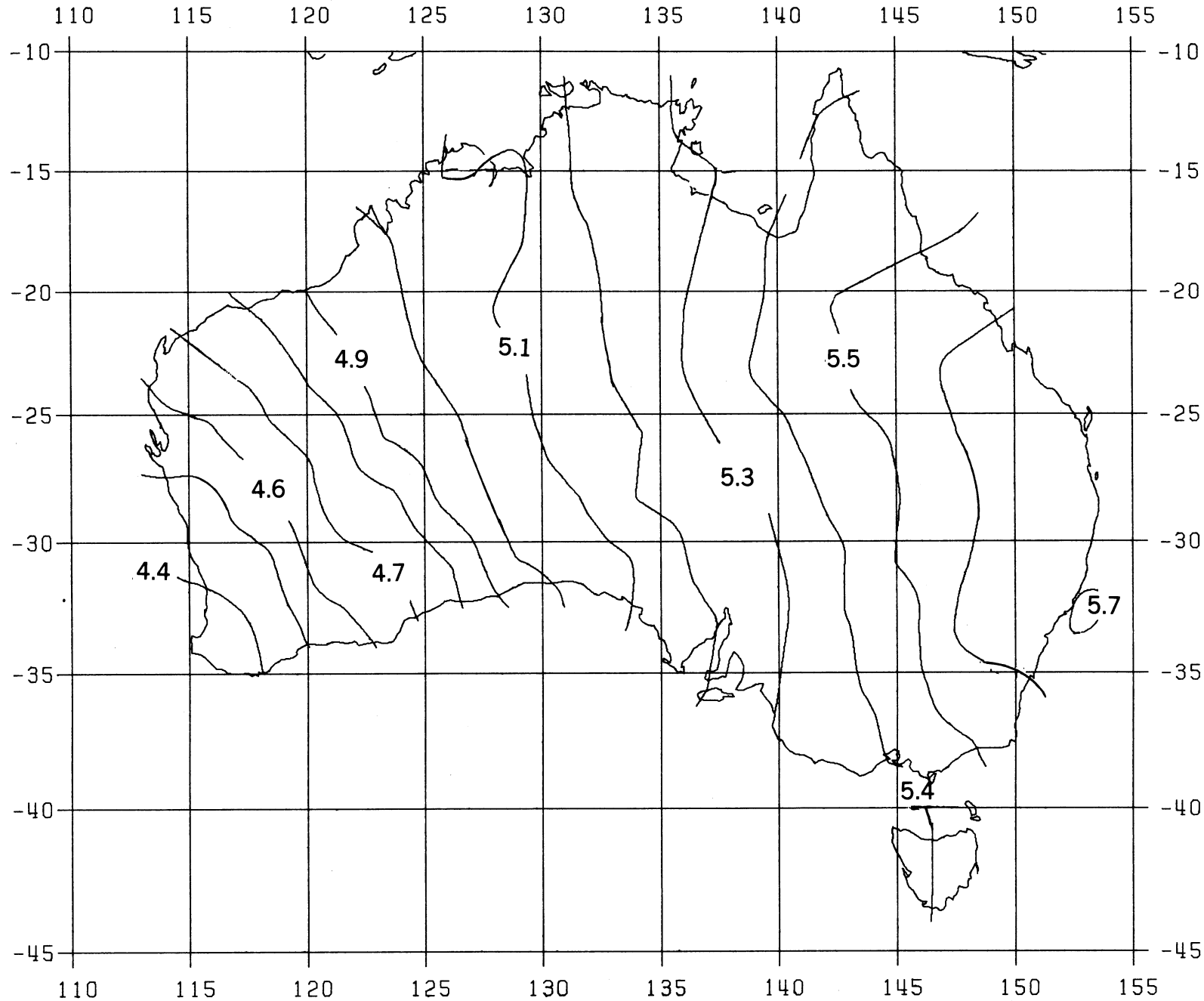

Figure 15.25. Contour Chart – Latitude Differences, WGS 84 Minus AGD 84 (Contour Interval = 0.1 Arc Second)

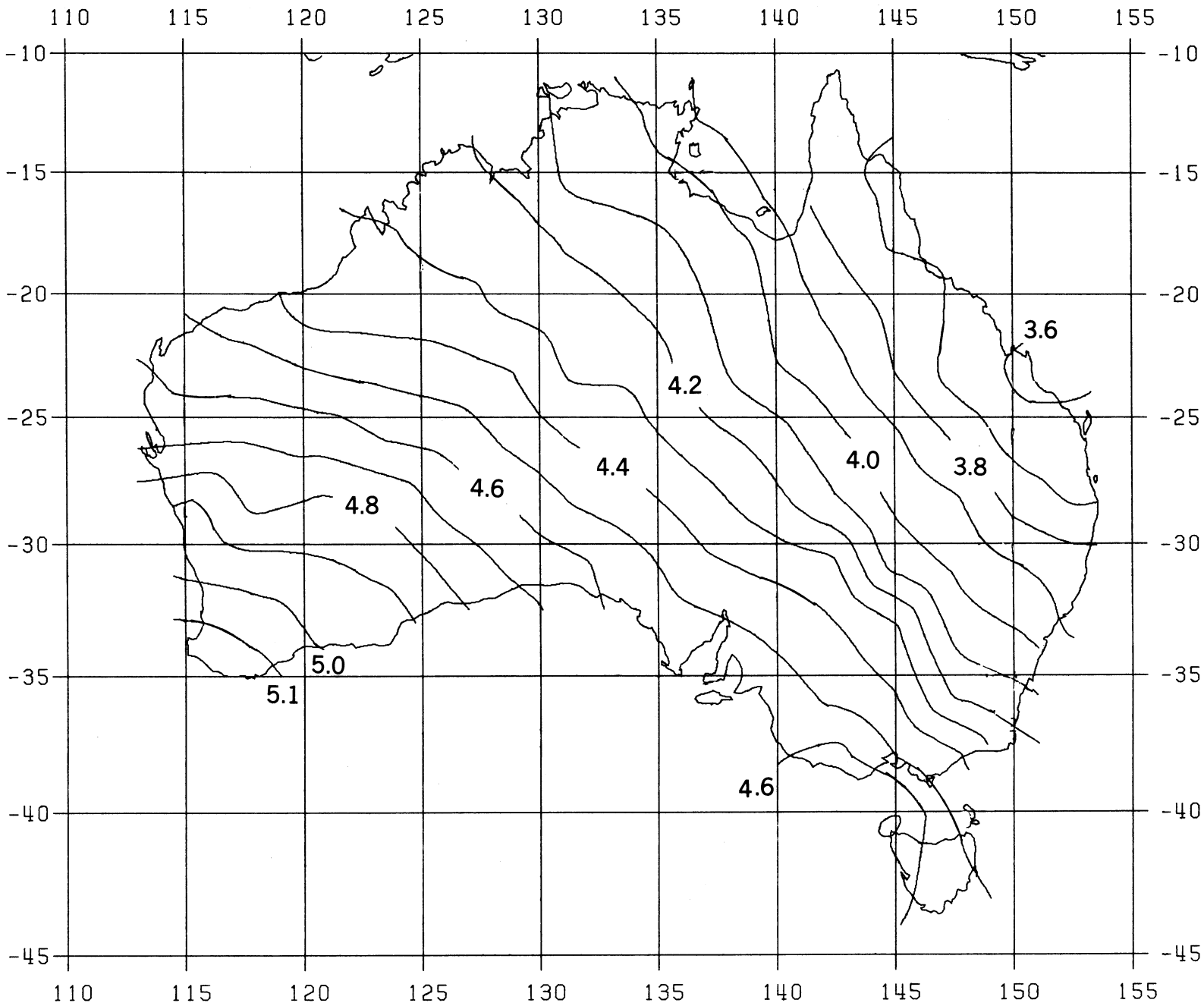

Figure 15.26. Contour Chart – Longitude Differences, WGS 84 Minus AGD 84 (Contour Interval = 0.1 Arc Second)

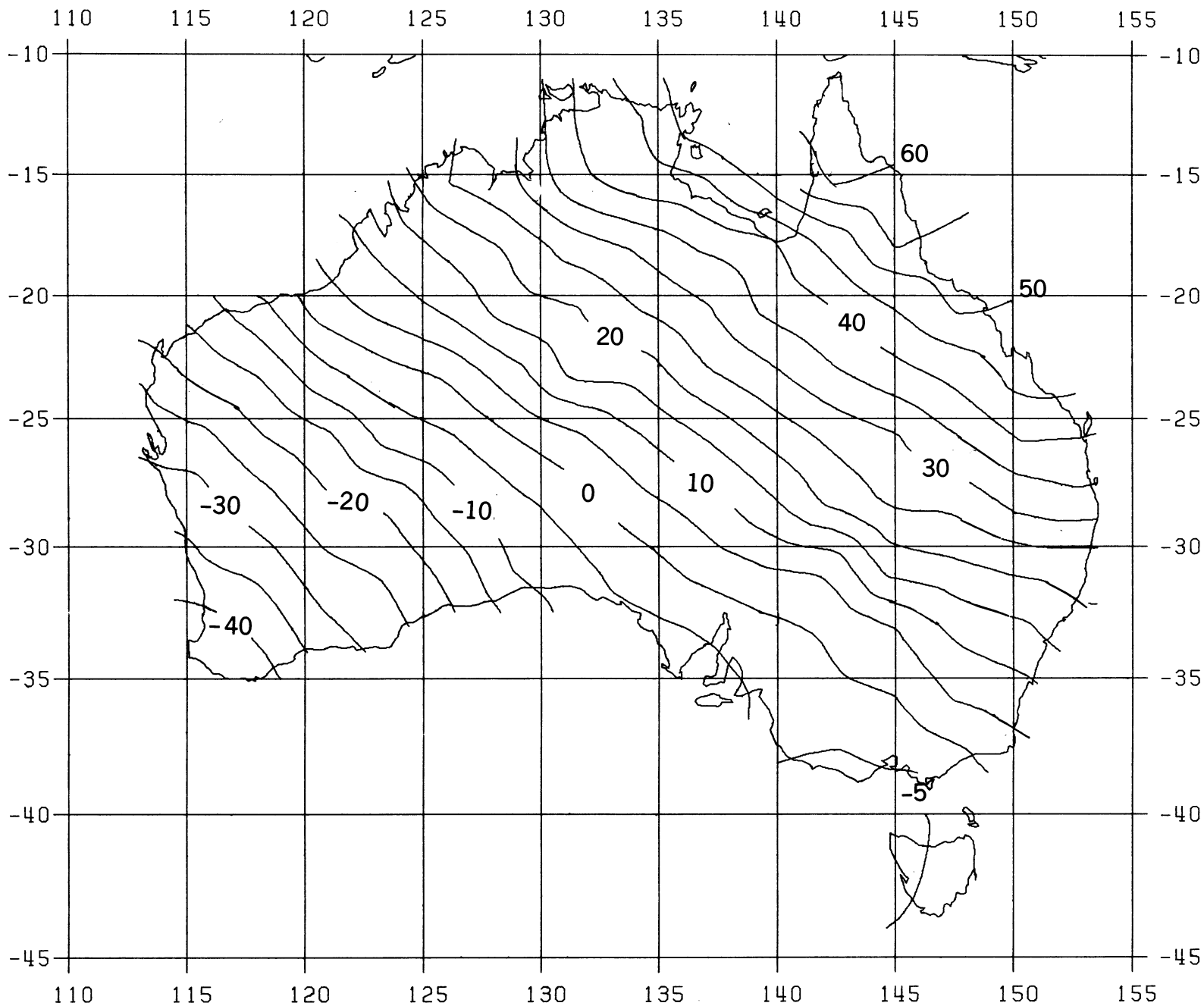

Figure 15.27. Contour Chart - Geodetic Height Differences, WGS 84 Minus AGD 84 (Contour Interval = 5 Meters)

SECTION 16

LOCAL GEODETIC SYSTEM-TO-WGS 84 DATUM SHIFTS

- $\Delta\phi$, $\Delta\lambda$, ΔH CONTOUR CHARTS FOR AN ADDITIONAL 29 OF THE 83 LOCAL GEODETIC SYSTEMS* -

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* CONTOUR CHARTS NOT INCLUDED FOR EUROPEAN DATUM 1979 (SINCE IT DOES NOT REPLACE ED 50), OR FOR THOSE LOCAL GEODETIC SYSTEMS WHERE THE USE OF DATUM SHIFT CONTOUR CHARTS WOULD HAVE LITTLE OR NO PRACTICAL VALUE (MOST ISLAND DATUMS AND/OR DATUMS WITH ONLY A VERY SMALL NUMBER OF DOPPLER DATUM TRANSFORMATION STATIONS, AND/OR DATUMS REPRESENTING SMALL GEOGRAPHICAL AREAS). FOR $\Delta\phi$, $\Delta\lambda$, ΔH VALUES FOR SUCH LOCAL GEODETIC SYSTEMS, SEE SECTION 20 (IN PARTICULAR, TABLE 20.46), OR UTILIZE TABLES 6.4 AND 10.1. THE FOOTNOTE TO PAGE 15-1 ALSO APPLIES HERE (SECTION 16).

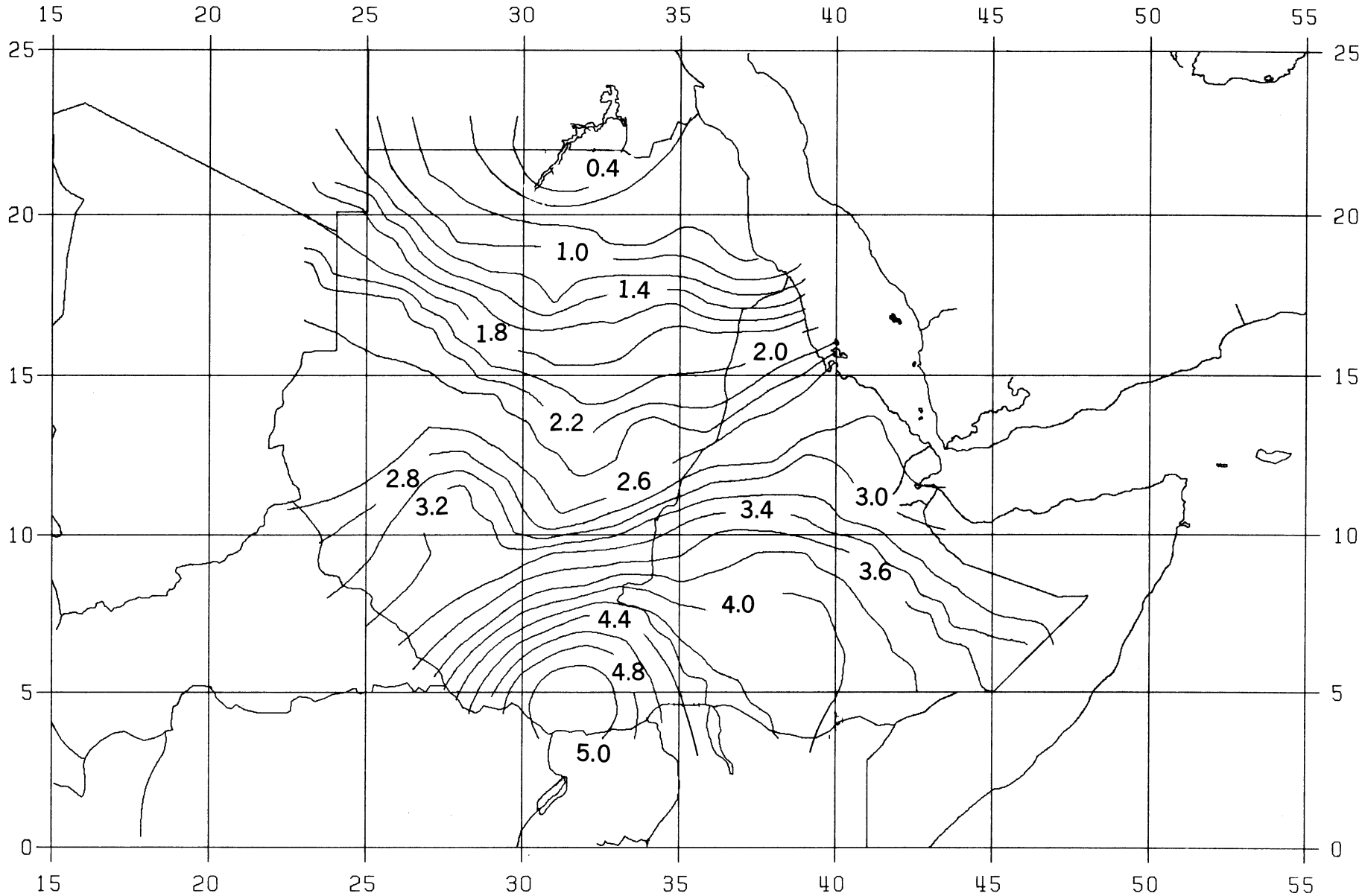

Figure 16.1. Contour Chart – Latitude Differences, WGS 84 Minus Adindan Datum (Contour Interval = 0.2 Arc Second)

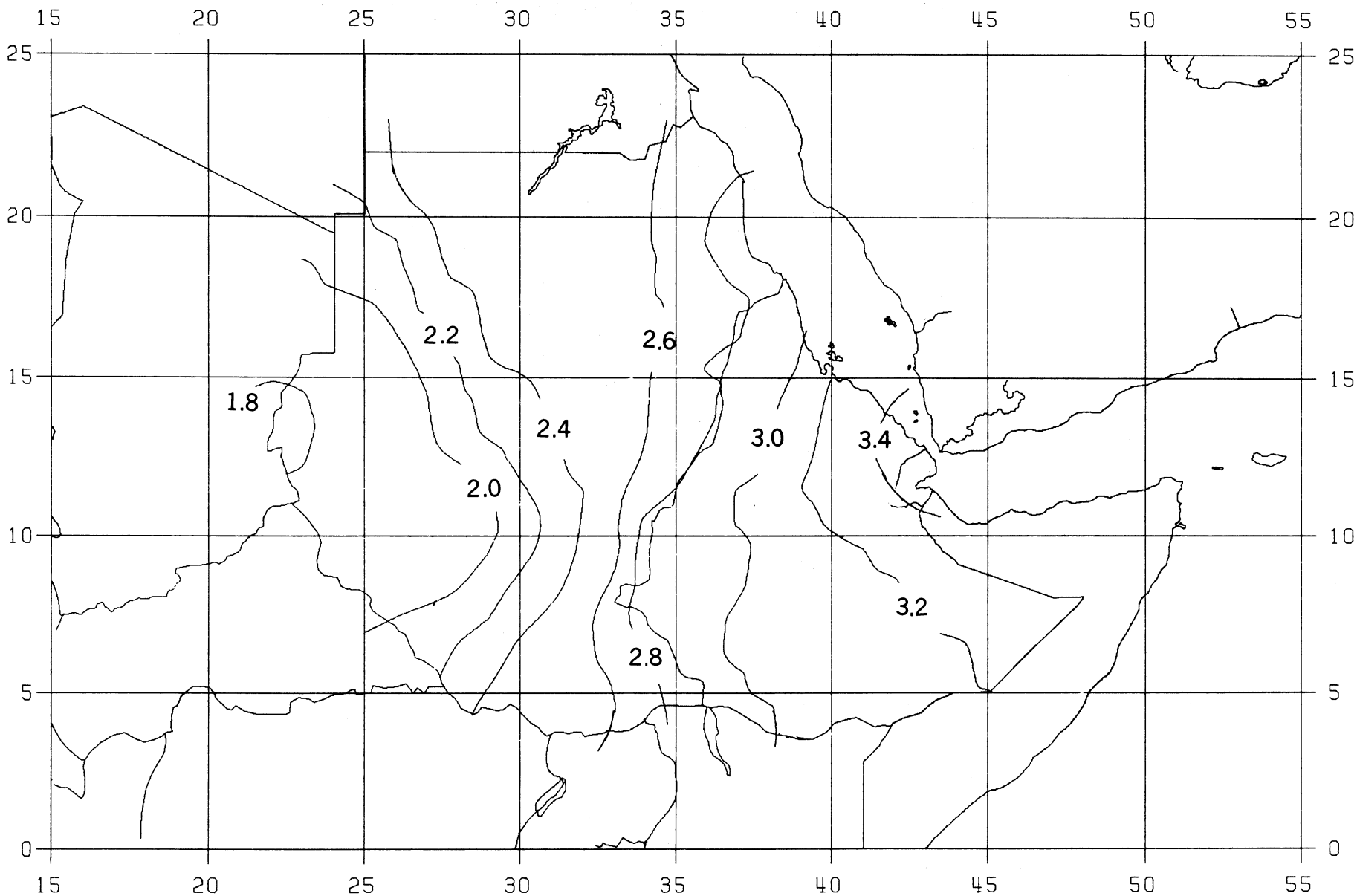

Figure 16.2. Contour Chart – Longitude Differences, WGS 84 Minus Adindan Datum (Contour Interval = 0.2 Arc Second)

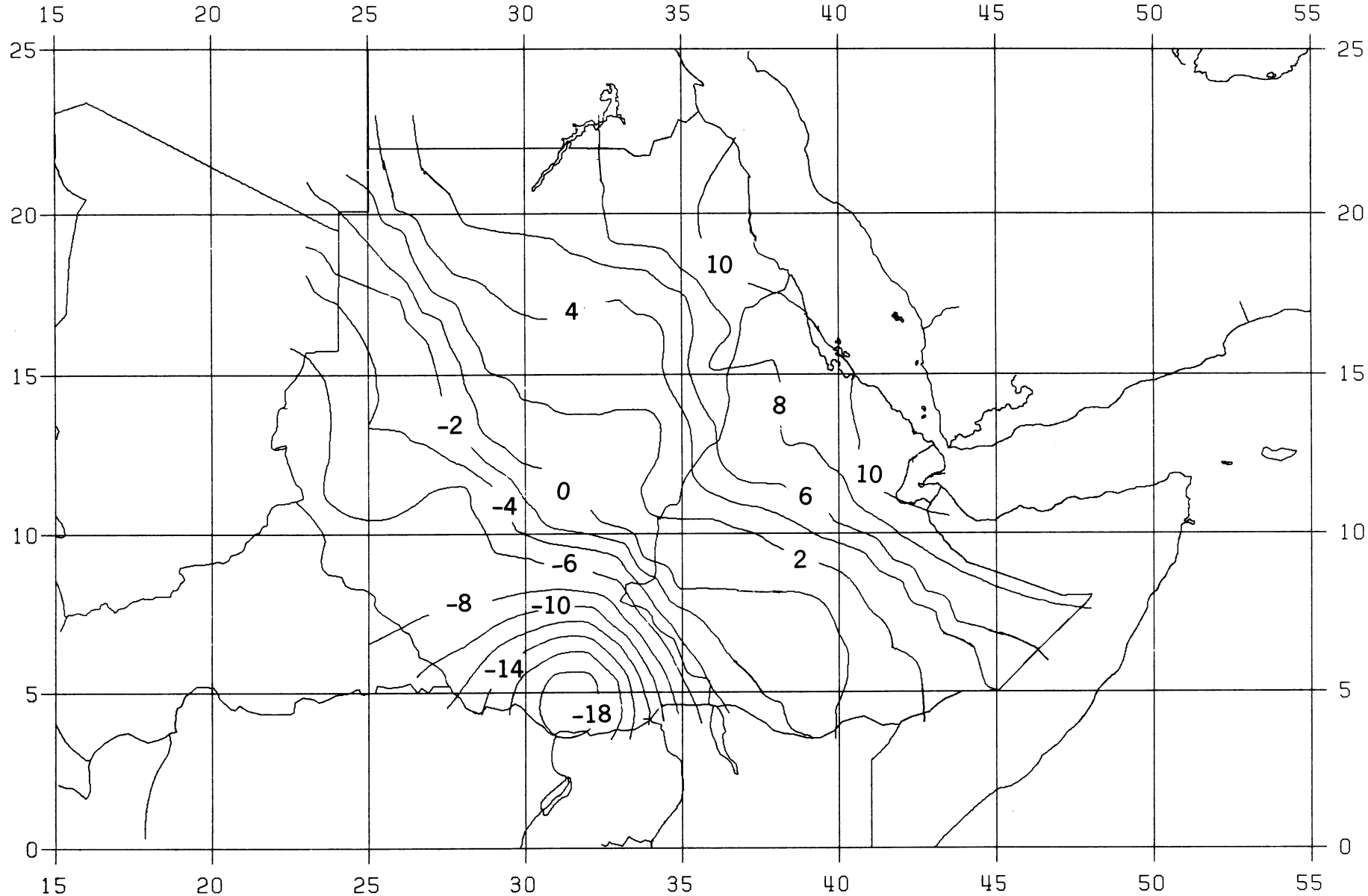

Figure 16.3. Contour Chart – Geodetic Height Differences, WGS 84 Minus Adindan Datum (Contour Interval = 2 Meters)

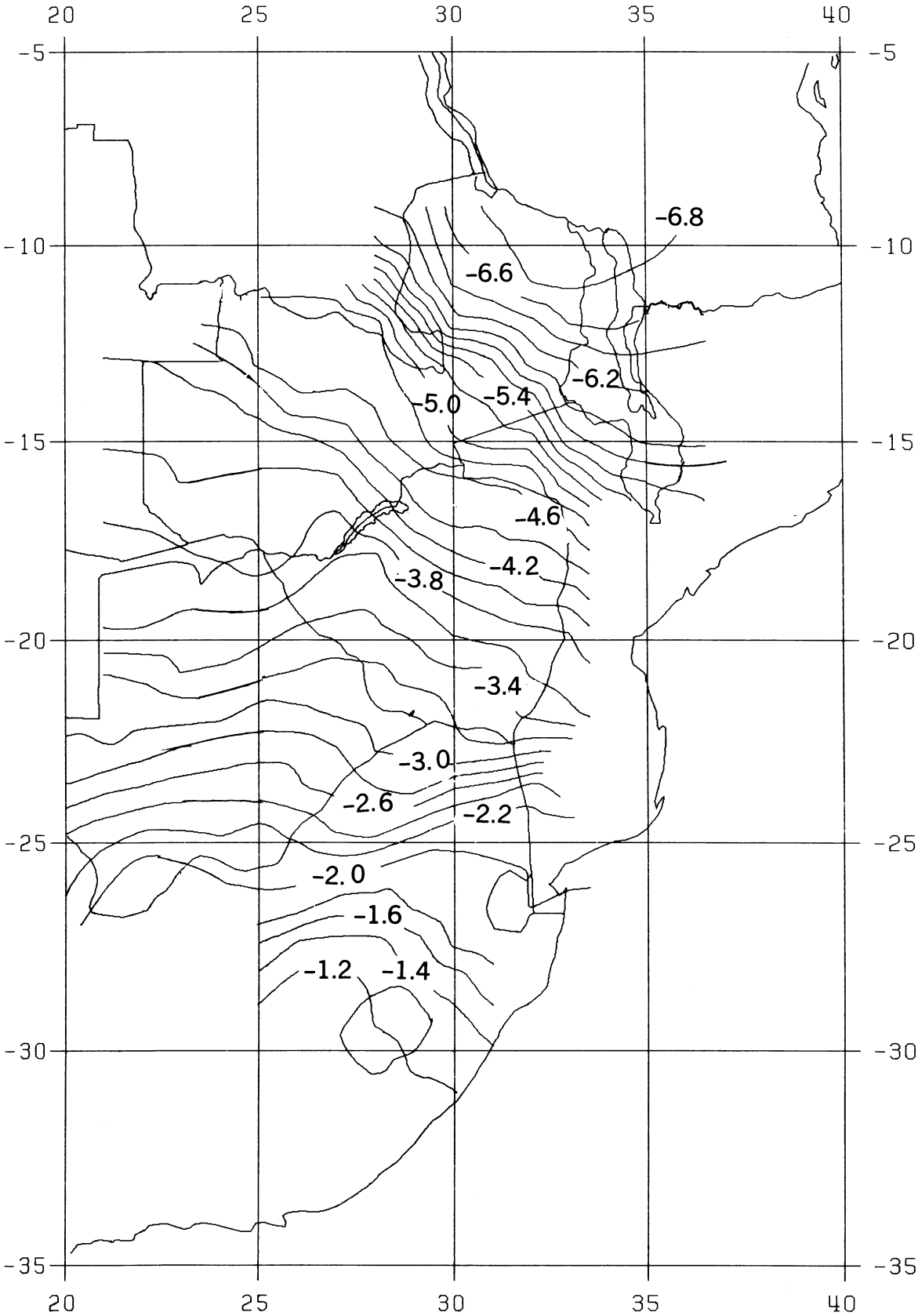

Figure 16.4. Contour Chart – Latitude Differences, WGS 84 Minus Arc Datum 1950
(Contour Interval = 0.2 Arc Second)

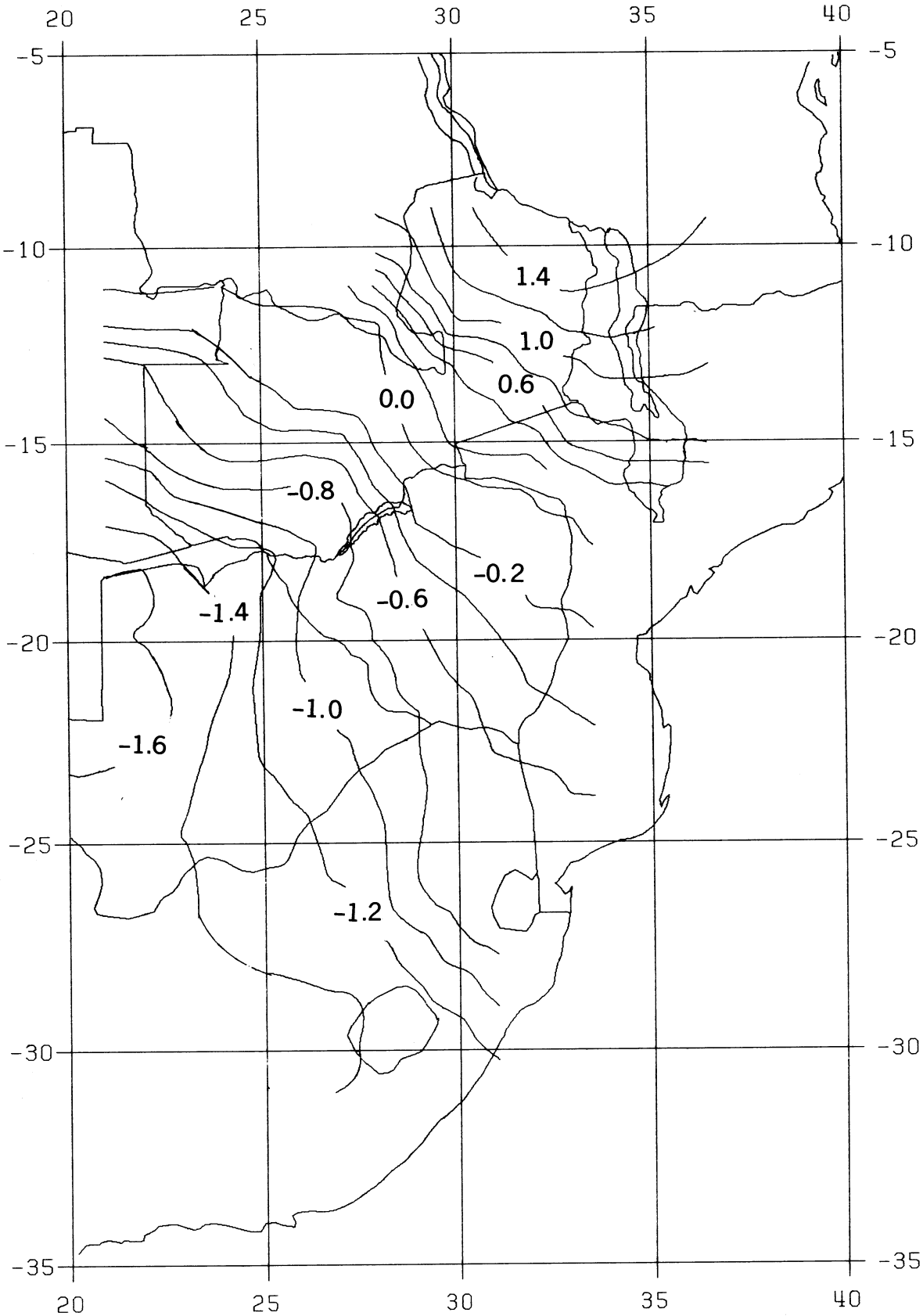

Figure 16.5. Contour Chart – Longitude Differences, WGS 84 Minus Arc Datum 1950
(Contour Interval = 0.2 Arc Second)

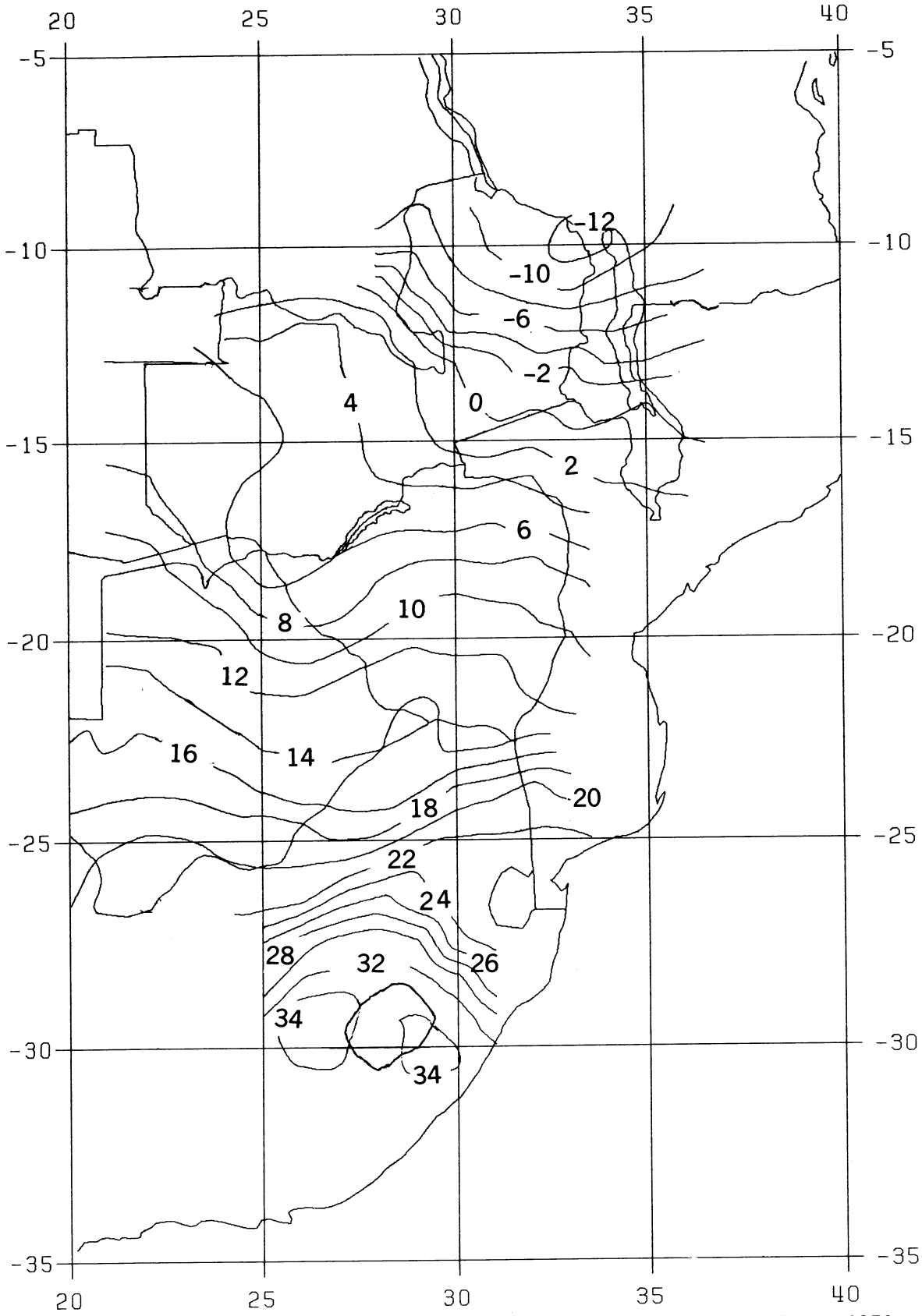

Figure 16.6. Contour Chart – Geodetic Height Differences, WGS 84 Minus Arc Datum 1950 (Contour Interval = 2 Meters)

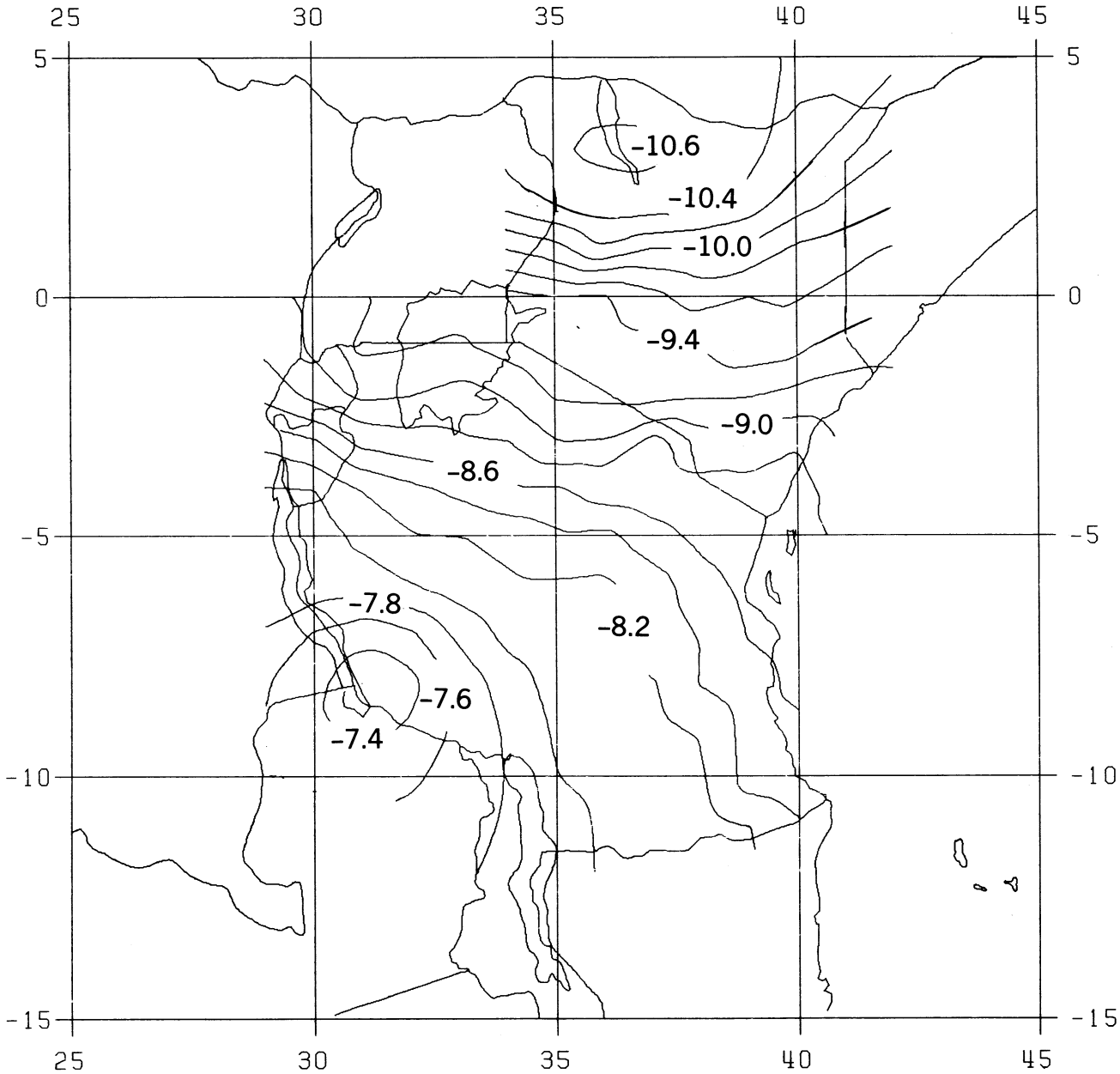

Figure 16.7. Contour Chart – Latitude Differences, WGS 84 Minus Arc Datum 1960
(Contour Interval = 0.2 Arc Second)

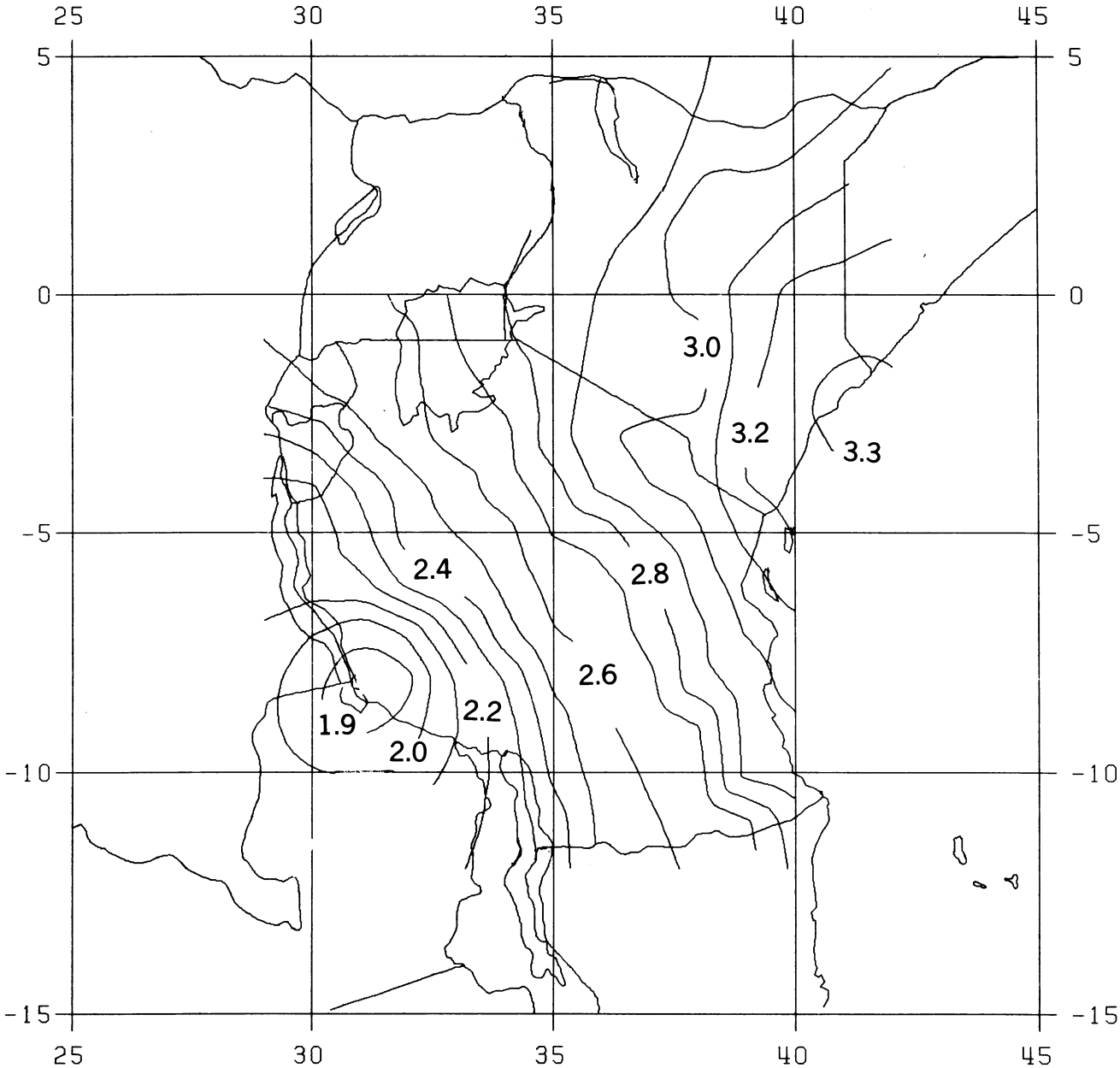

Figure 16.8. Contour Chart - Longitude Differences, WGS 84 Minus Arc Datum 1960
(Contour Interval = 0.1 Arc Second)

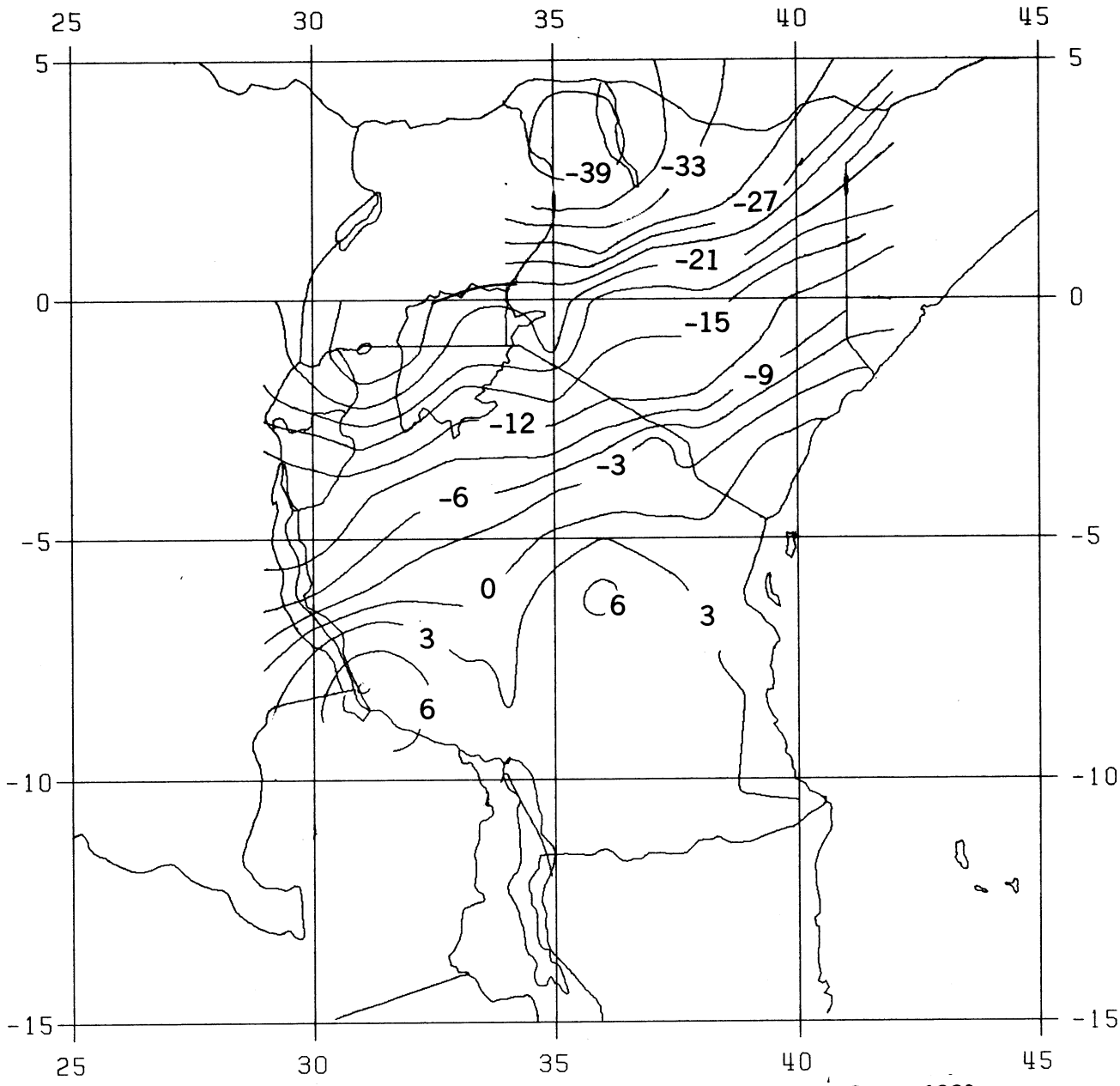

Figure 16.9. Contour Chart - Geodetic Height Differences, WGS 84 Minus Arc Datum 1960 (Contour Interval = 3 Meters)

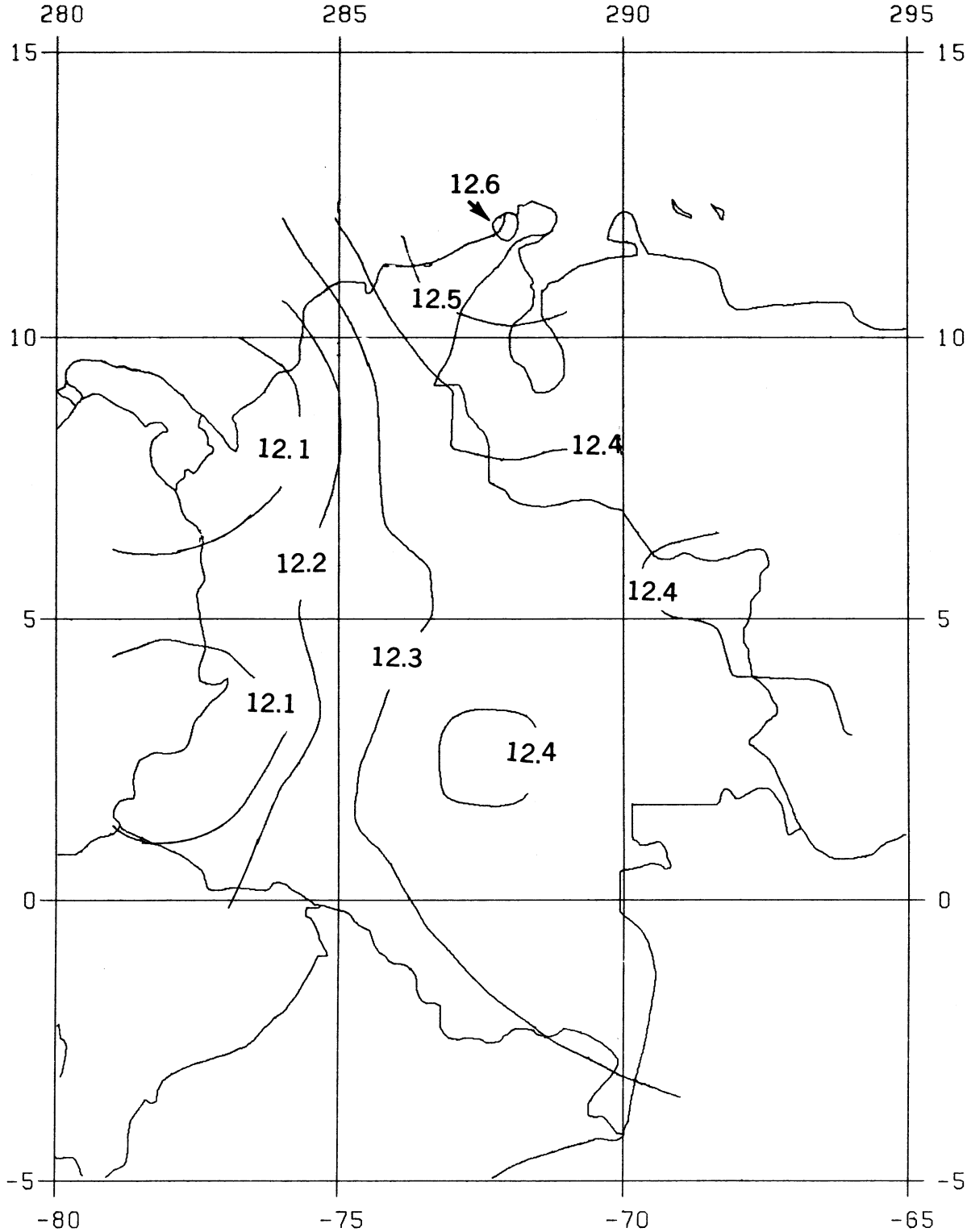

Figure 16.10. Contour Chart - Latitude Differences, WGS 84 Minus Bogota Observatory Datum (Contour Interval = 0.1 Arc Second)

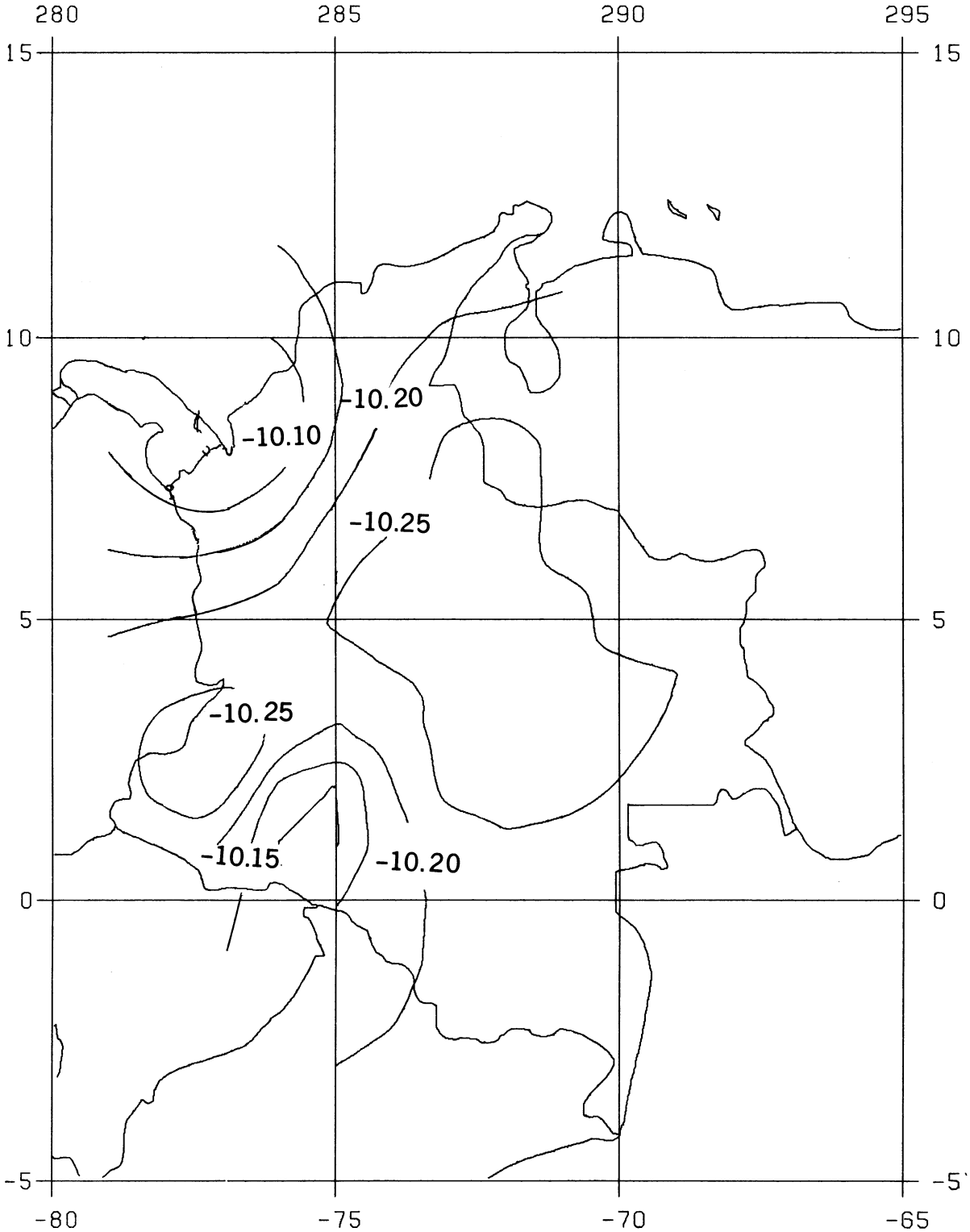

Figure 16.11. Contour Chart - Longitude Differences, WGS 84 Minus Bogota Observatory Datum (Contour Interval = 0.05 Arc Second)

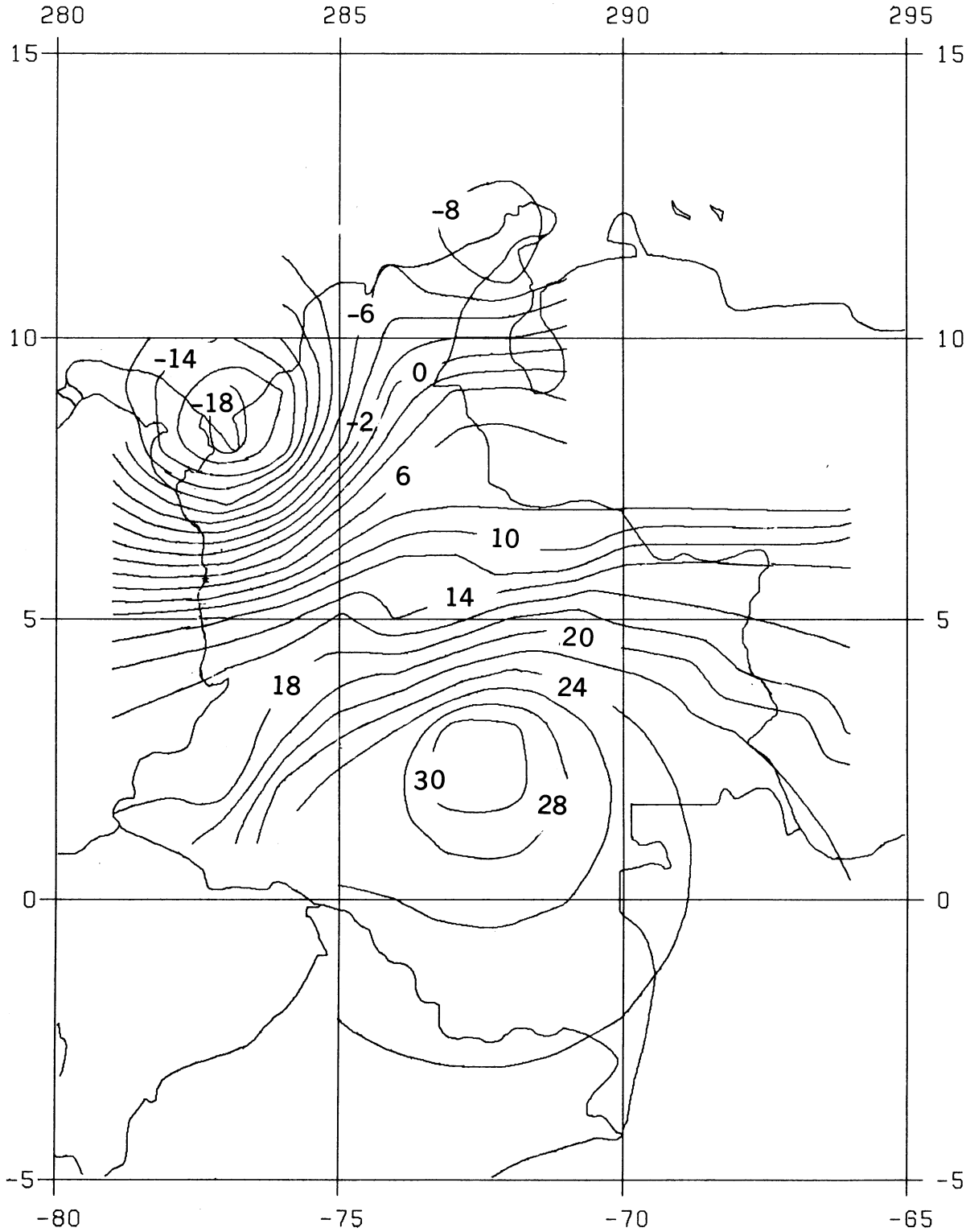

Figure 16.12. Contour Chart - Geodetic Height Differences, WGS 84 Minus Bogota Observatory Datum (Contour Interval = 2 Meters)

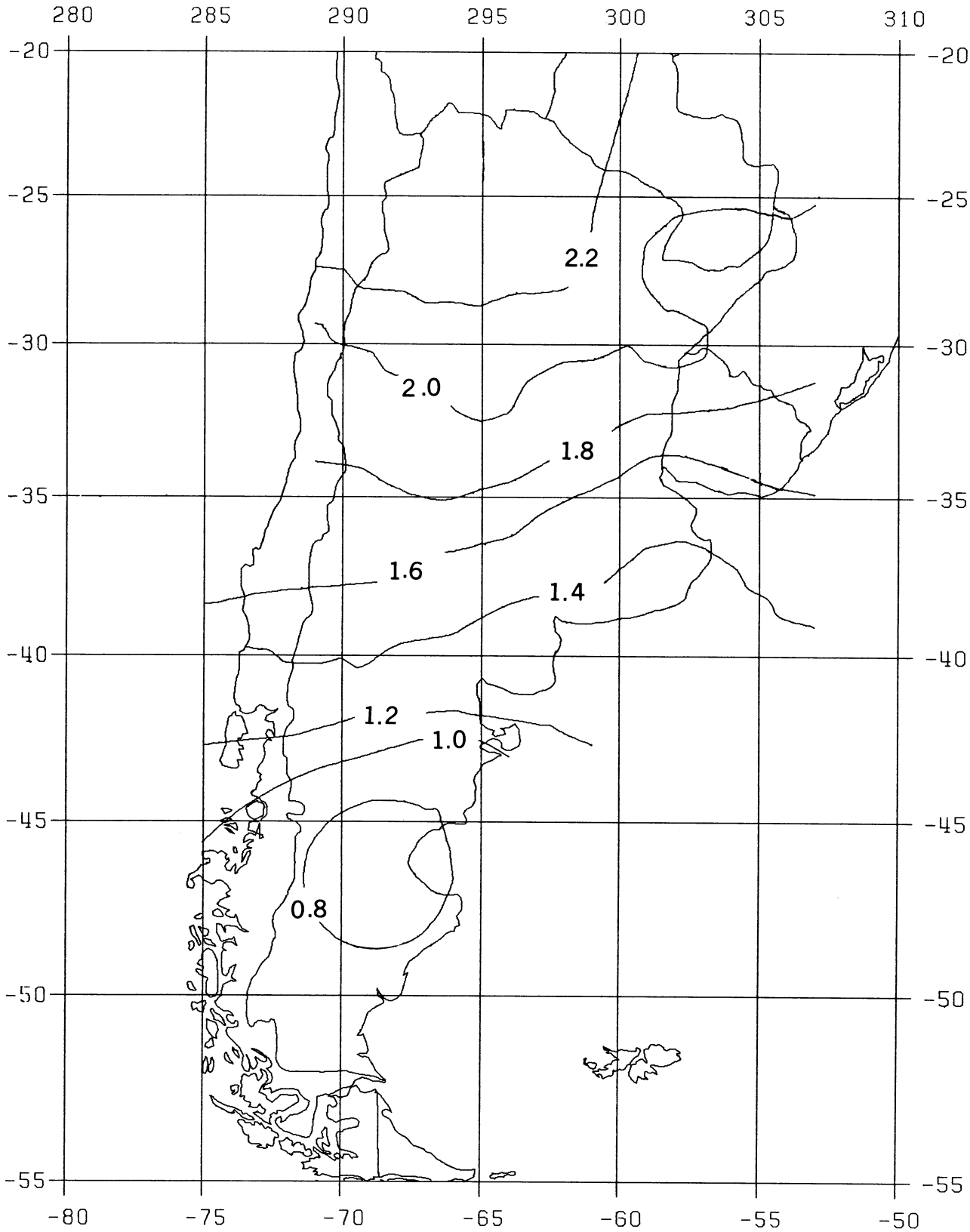

Figure 16.13. Contour Chart – Latitude Differences, WGS 84 Minus Campo Inchauspe Datum (Contour Interval = 0.2 Arc Second)

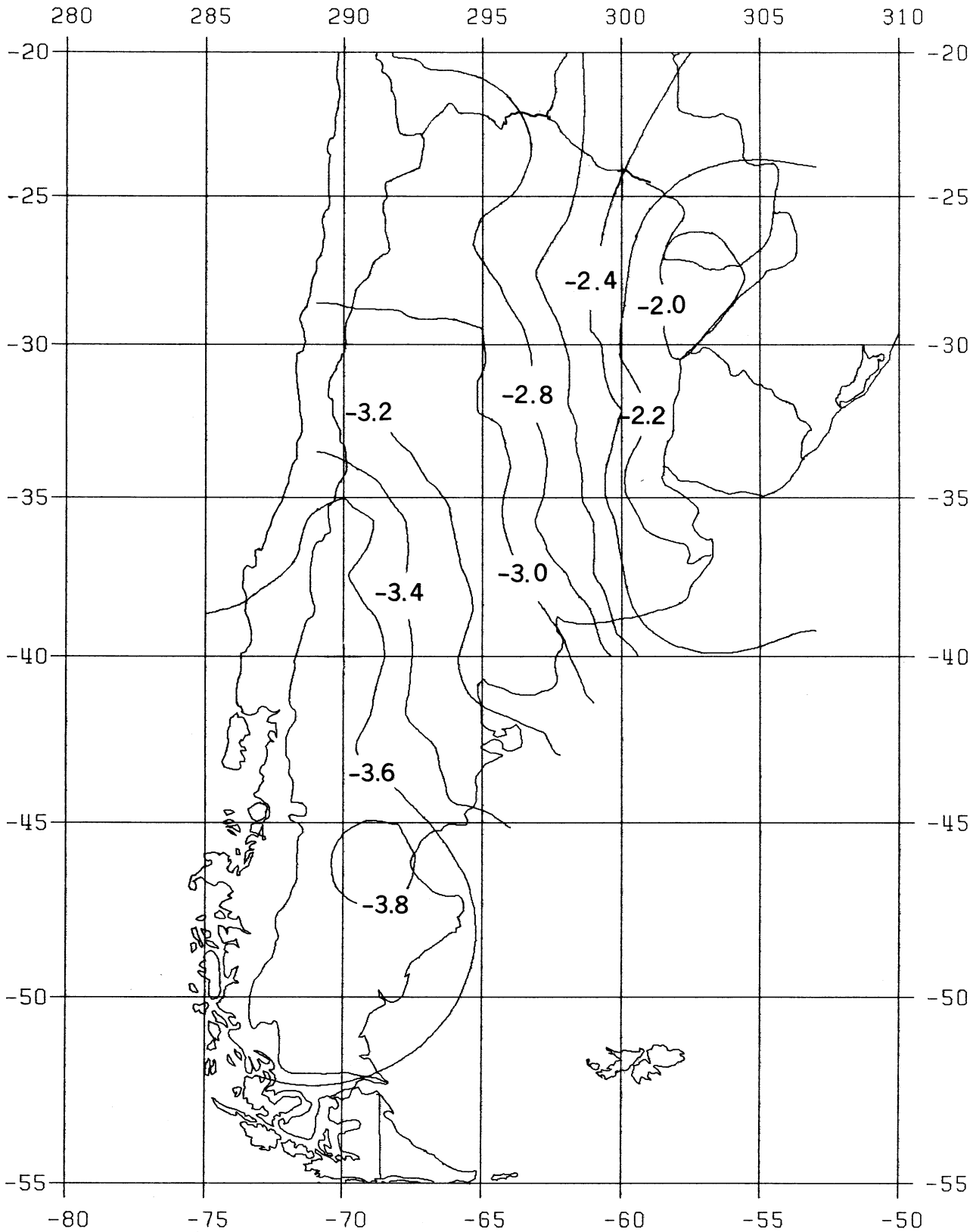

Figure 16.14. Contour Chart - Longitude Differences, WGS 84 Minus Campo Inchauspe Datum (Contour Interval = 0.2 Arc Second)

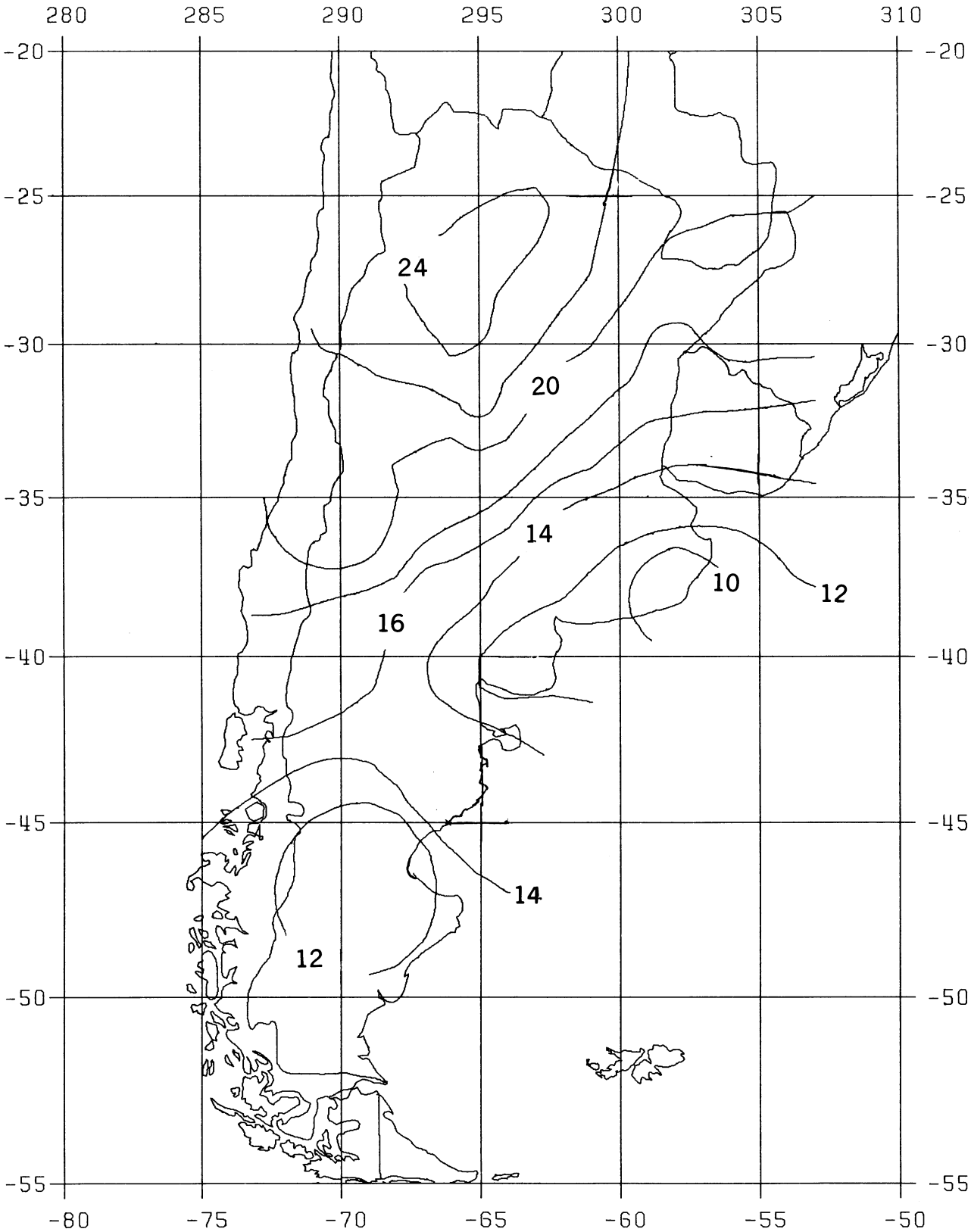

Figure 16.15. Contour Chart - Geodetic Height Differences, WGS 84 Minus Campo Inchauspe Datum (Contour Interval = 2 Meters)

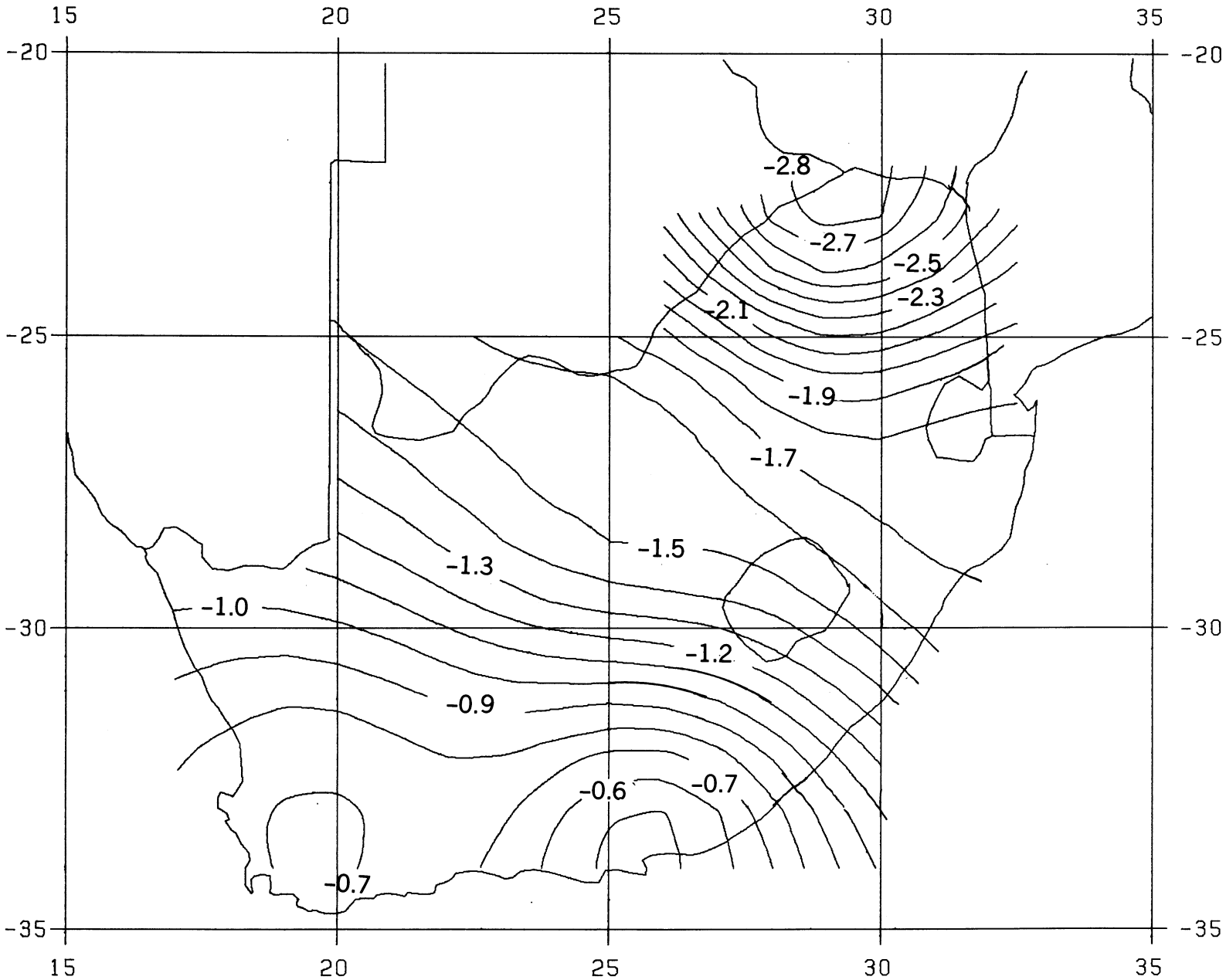

Figure 16.16. Contour Chart – Latitude Differences, WGS 84 Minus Cape Datum (Contour Interval = 0.1 Arc Second)

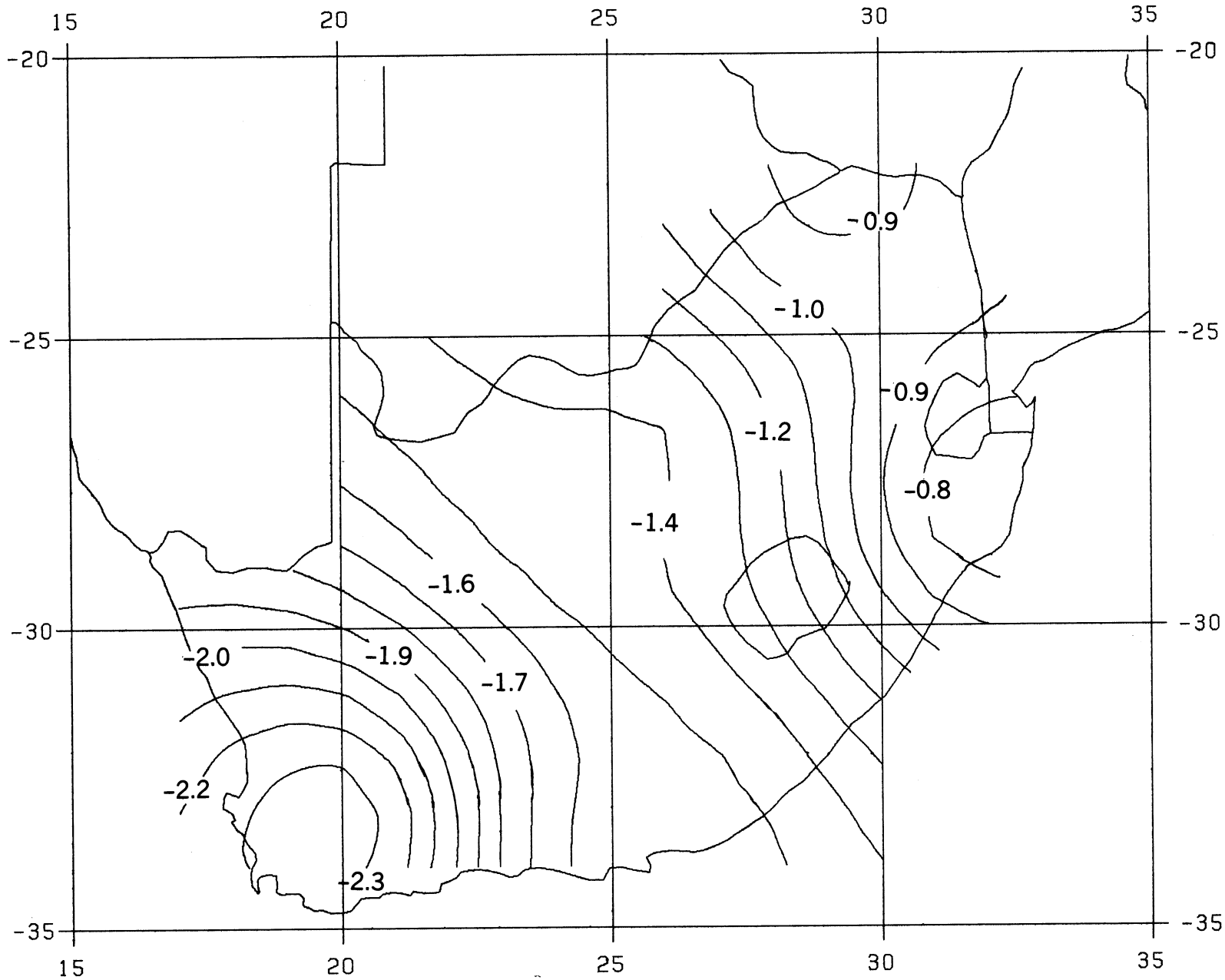

Figure 16.17. Contour Chart – Longitude Differences, WGS 84 Minus Cape Datum (Contour Interval = 0.1 Arc Second)

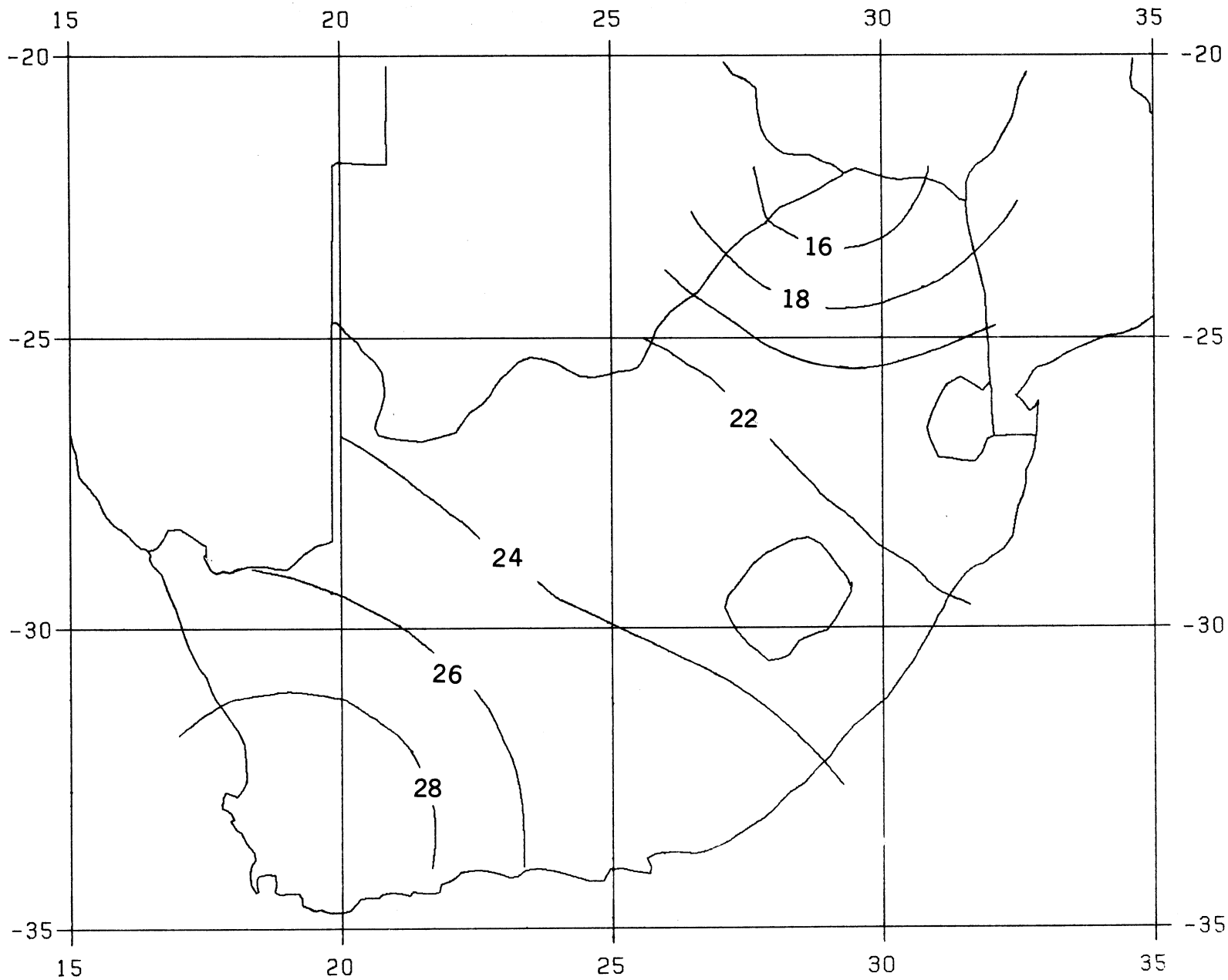

Figure 16.18. Contour Chart - Geodetic Height Differences, WGS 84 Minus Cape Datum (Contour Interval = 2 Meters)

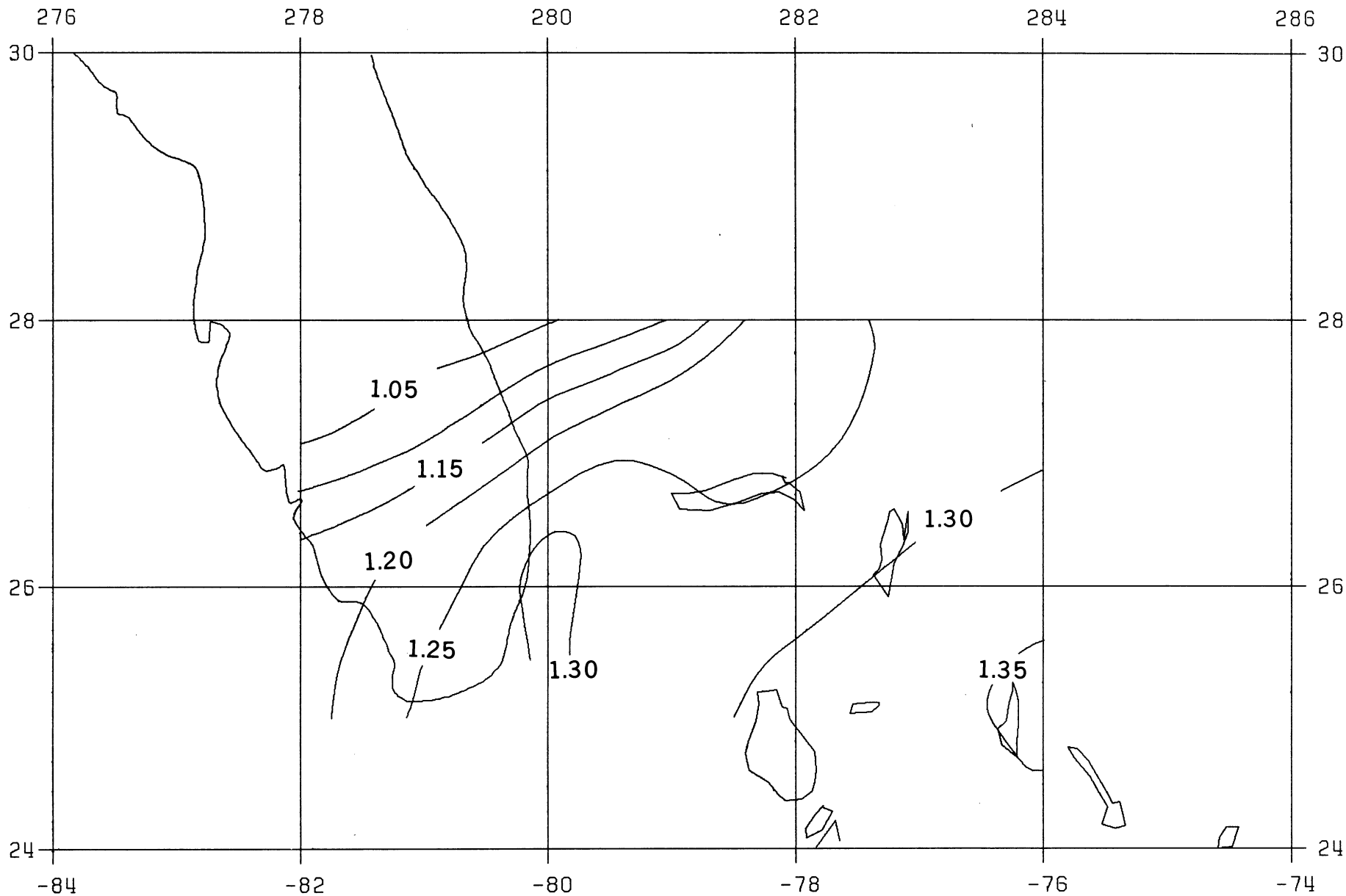

Figure 16.19. Contour Chart – Latitude Differences, WGS 84 Minus Cape Canaveral Datum (Contour Interval = 0.05 Arc Second)

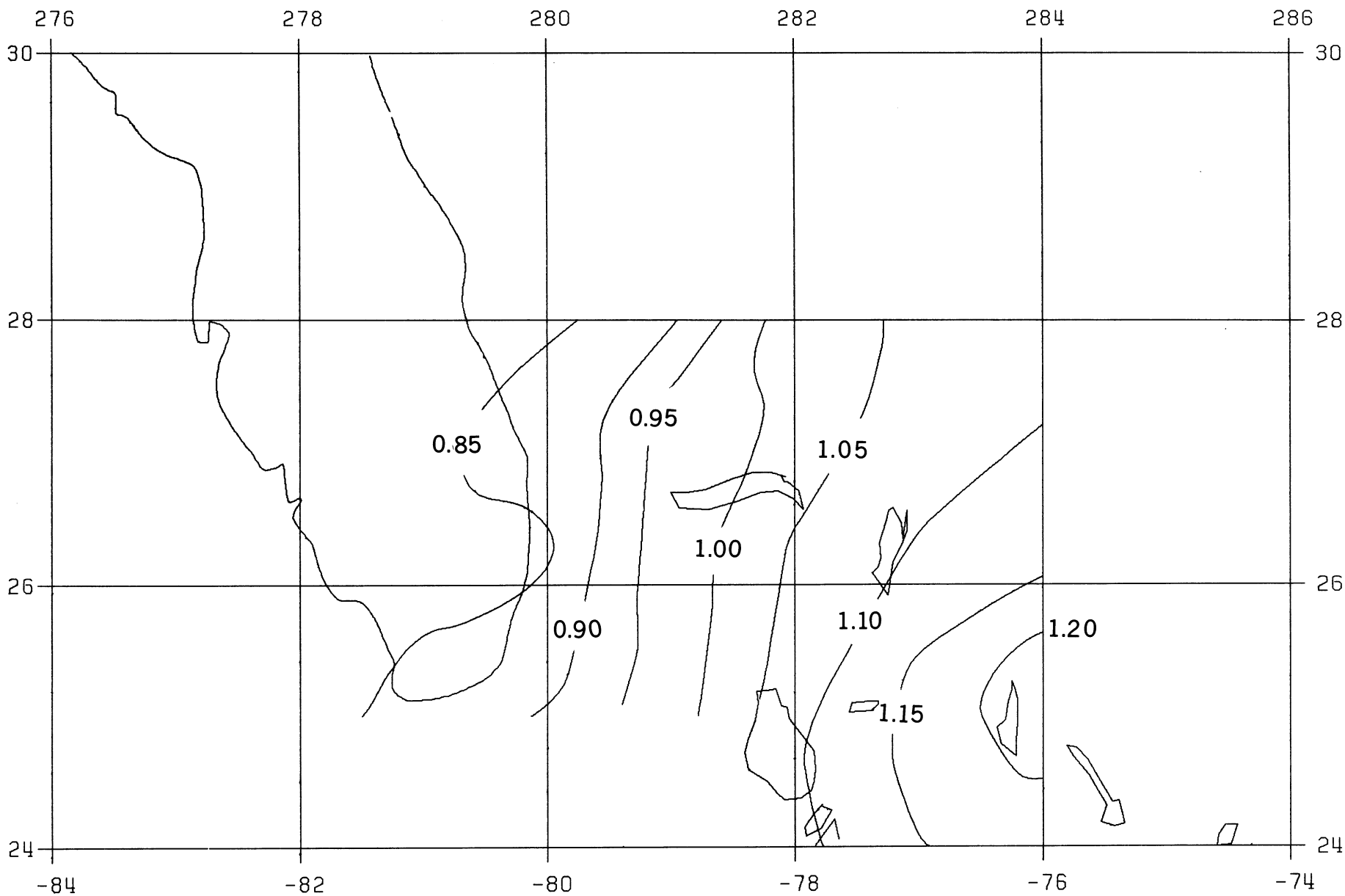

Figure 16.20. Contour Chart - Longitude Differences, WGS 84 Minus Cape Canaveral Datum (Contour Interval = 0.05 Arc Second)

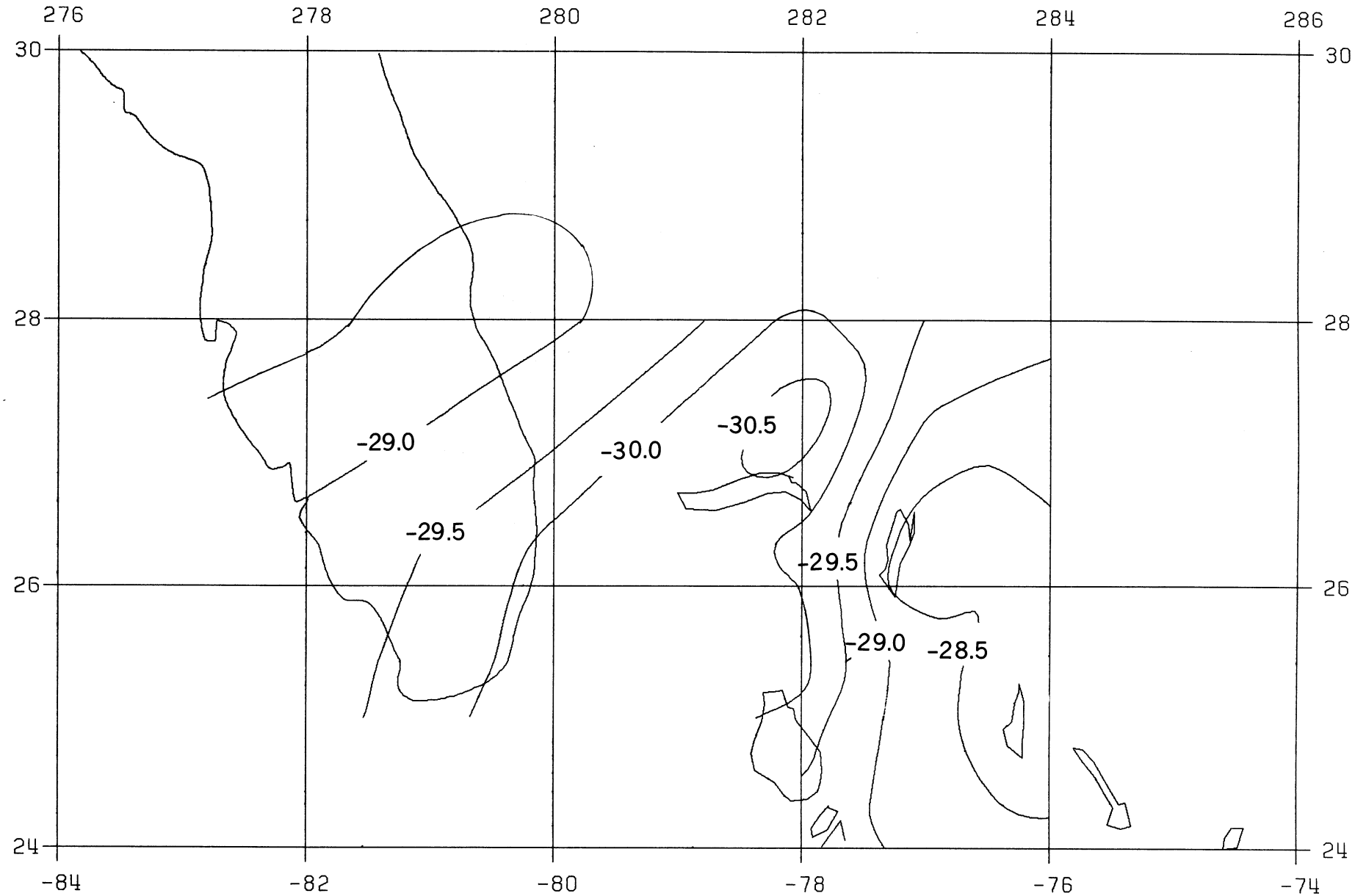

Figure 16.21. Contour Chart – Geodetic Height Differences, WGS 84 Minus Cape Canaveral Datum (Contour Interval = 0.5 Meters)

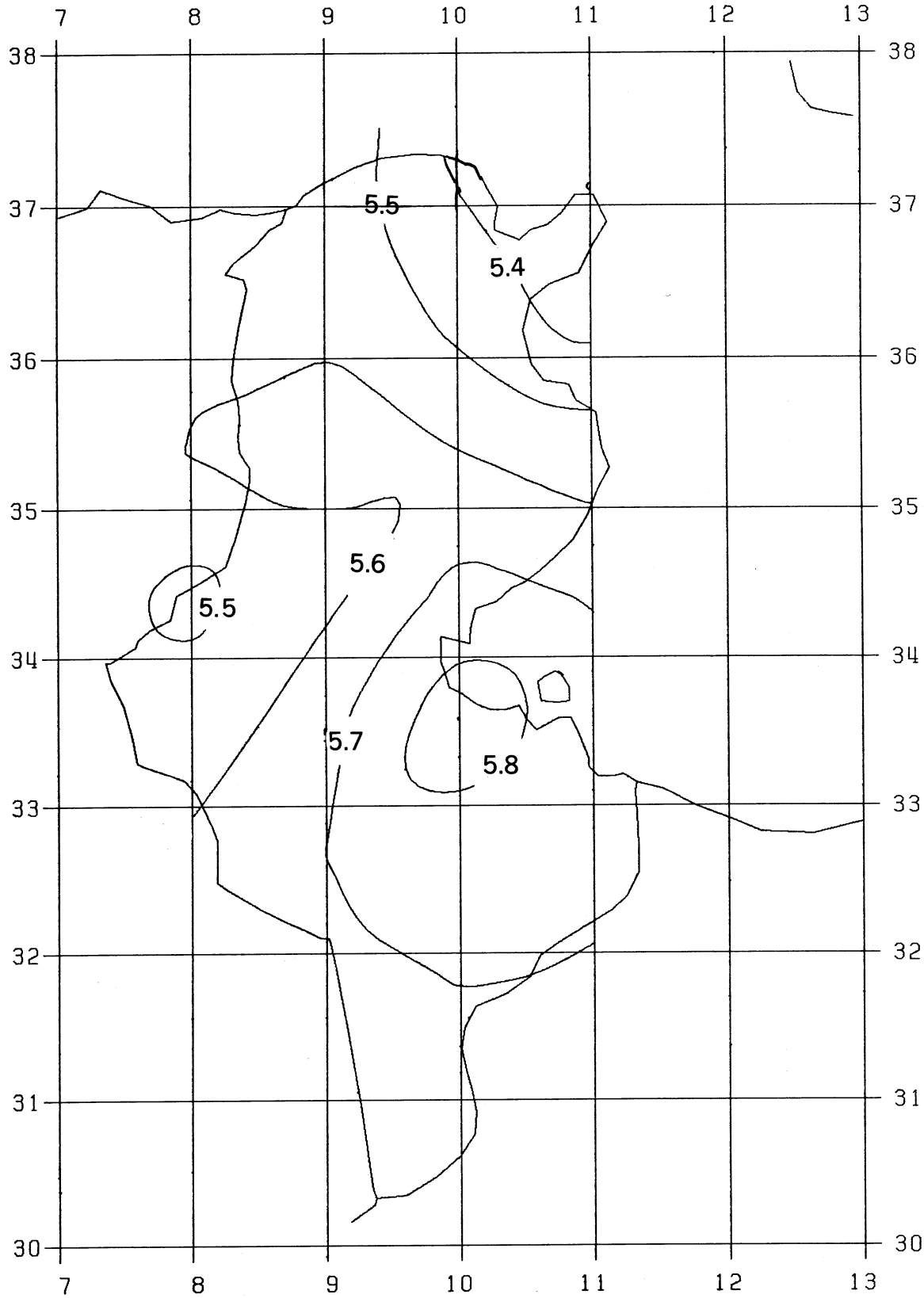

Figure 16.22. Contour Chart – Latitude Differences, WGS 84 Minus Carthage Datum (Contour Interval = 0.1 Arc Second)

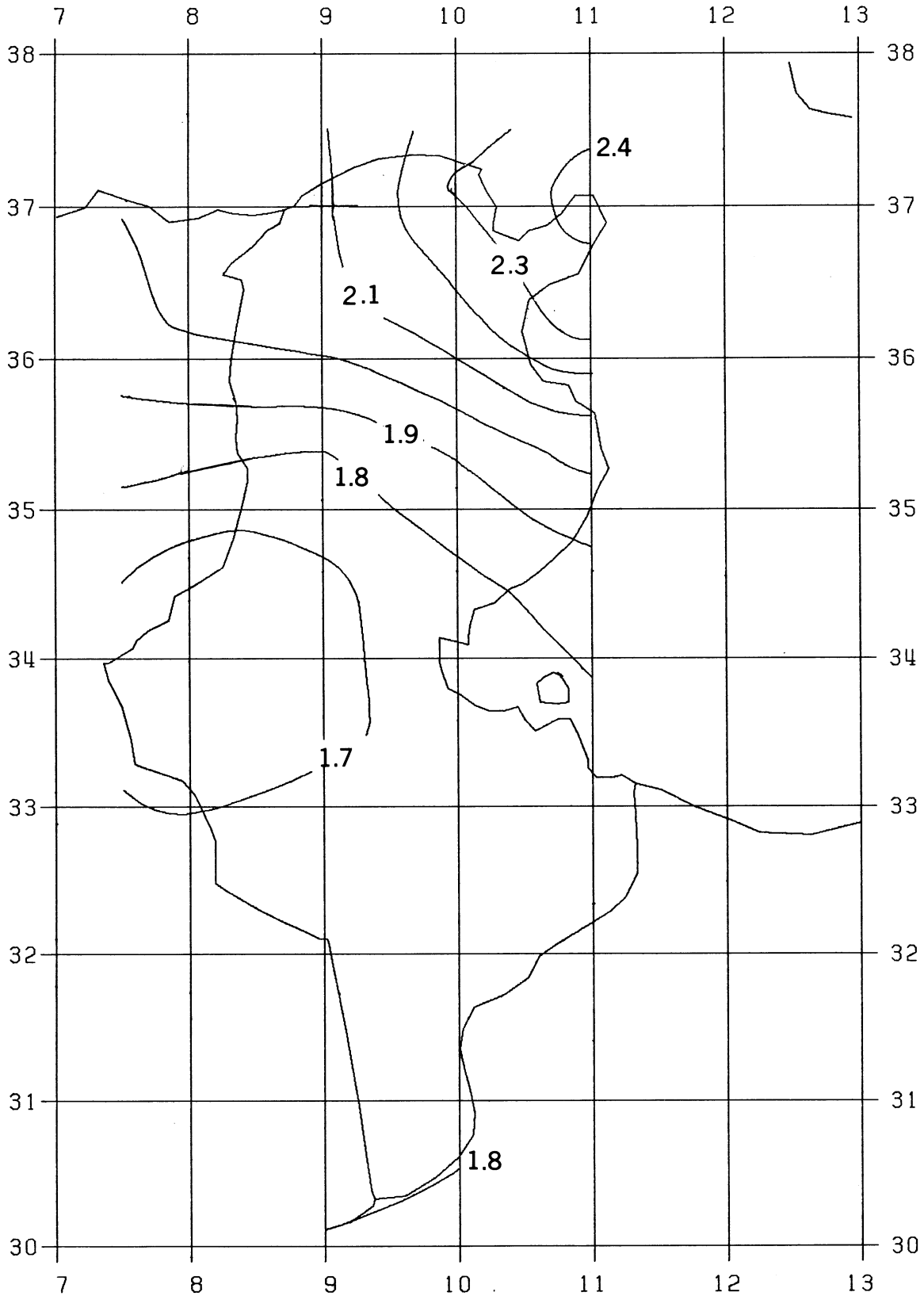

Figure 16.23. Contour Chart – Longitude Differences, WGS 84 Minus Carthage Datum (Contour Interval = 0.1 Arc Second)

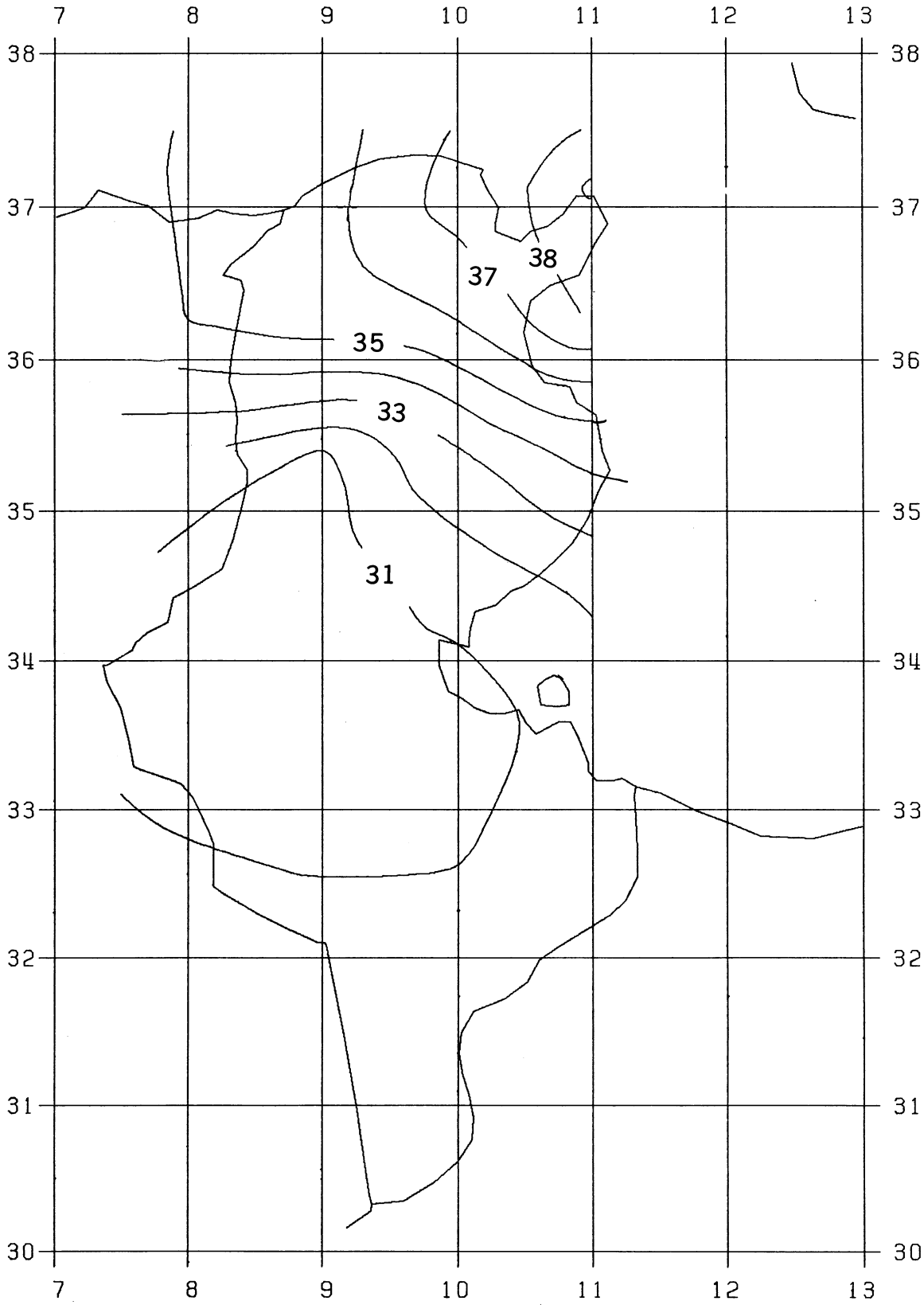

Figure 16.24. Contour Chart - Geodetic Height Differences, WGS 84 Minus Carthage Datum (Contour Interval = 1 Meter)

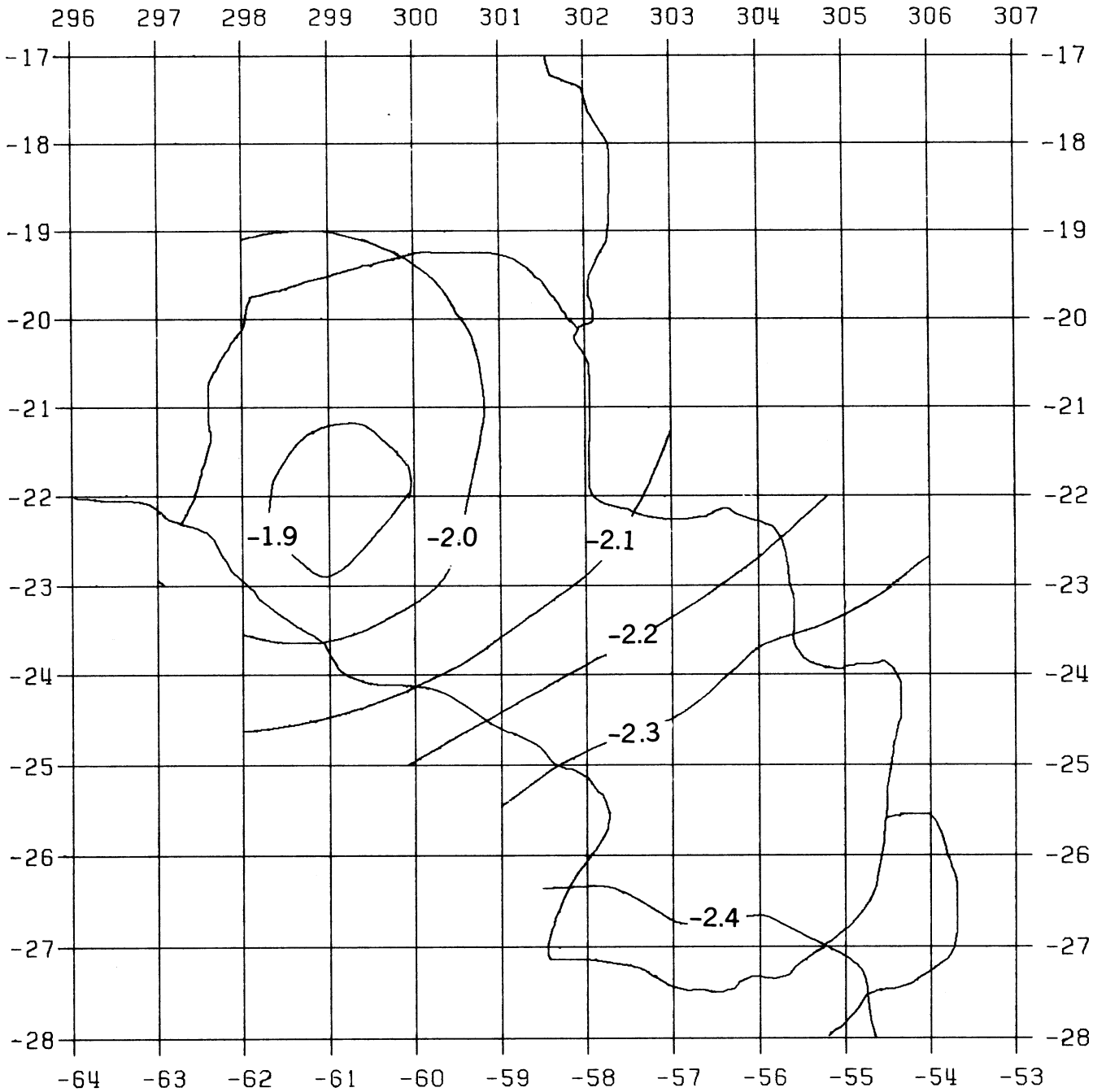

Figure 16.25. Contour Chart – Latitude Differences, WGS 84 Minus Chua Astro Datum (Contour Interval = 0.1 Arc Second)

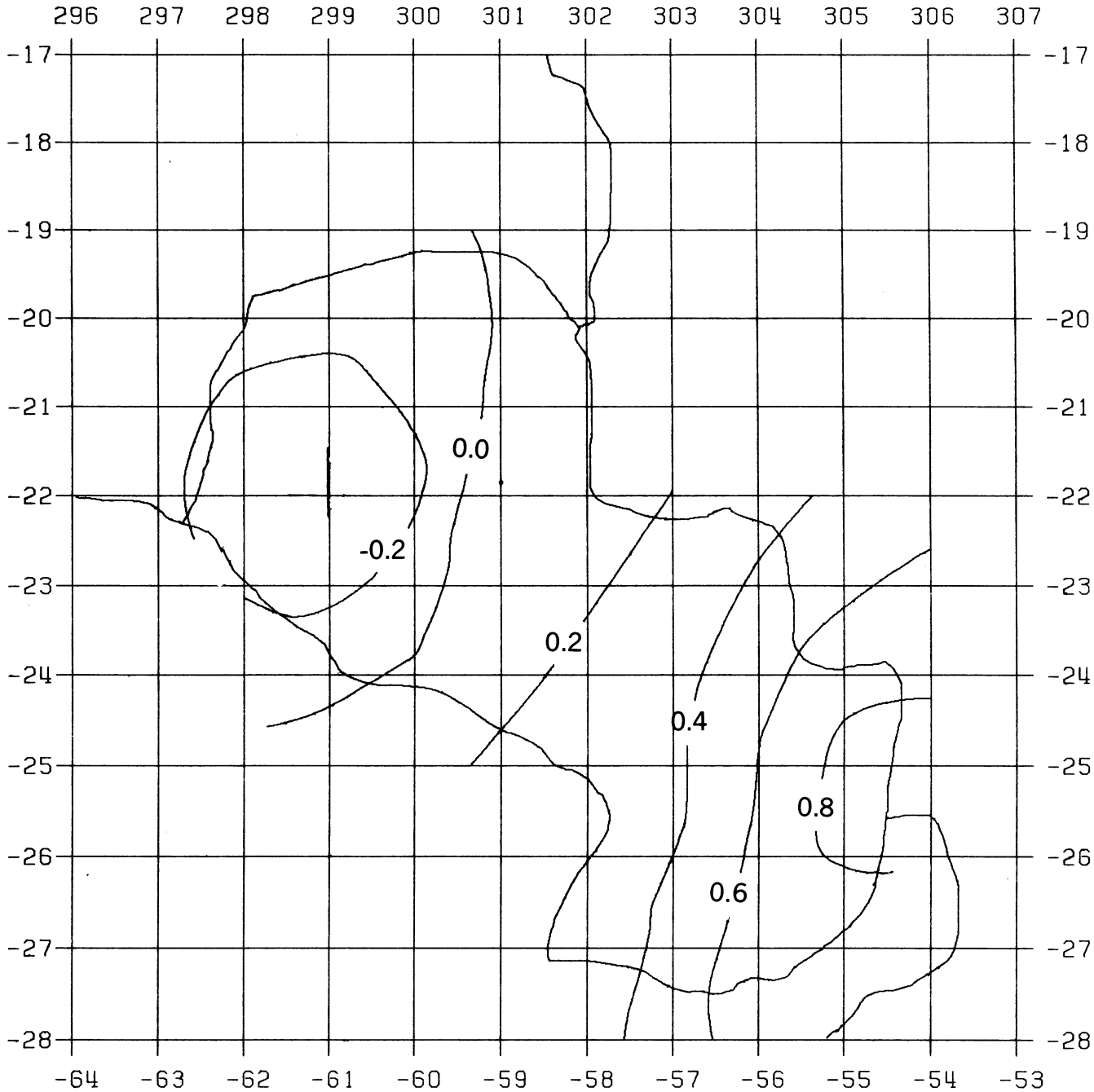

Figure 16.26. Contour Chart – Longitude Differences, WGS 84 Minus Chua Astro Datum (Contour Interval = 0.2 Arc Second)

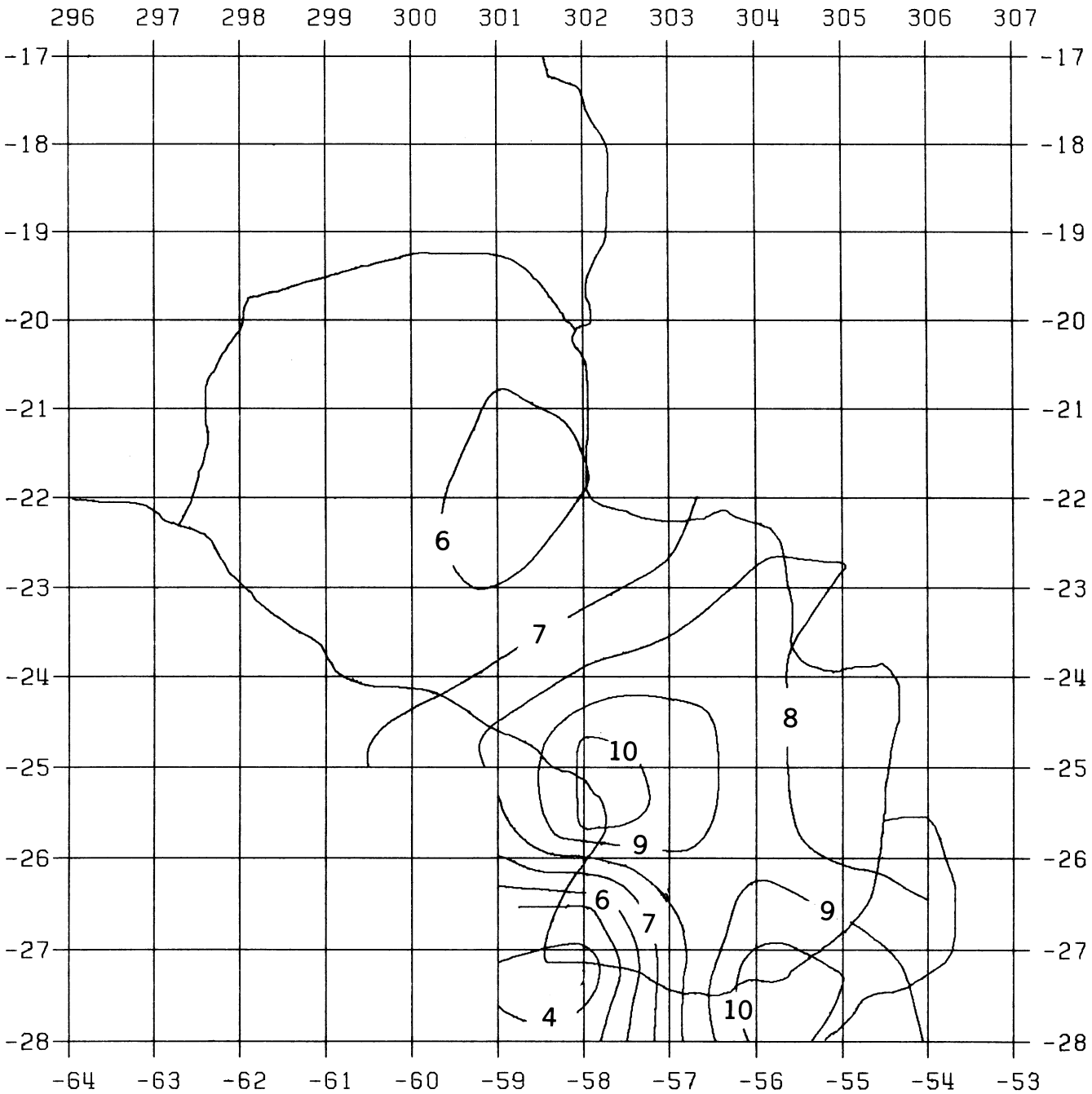

Figure 16.27. Contour Chart - Geodetic Height Differences, WGS 84 Minus Chua Astro Datum (Contour Interval = 1 Meter)

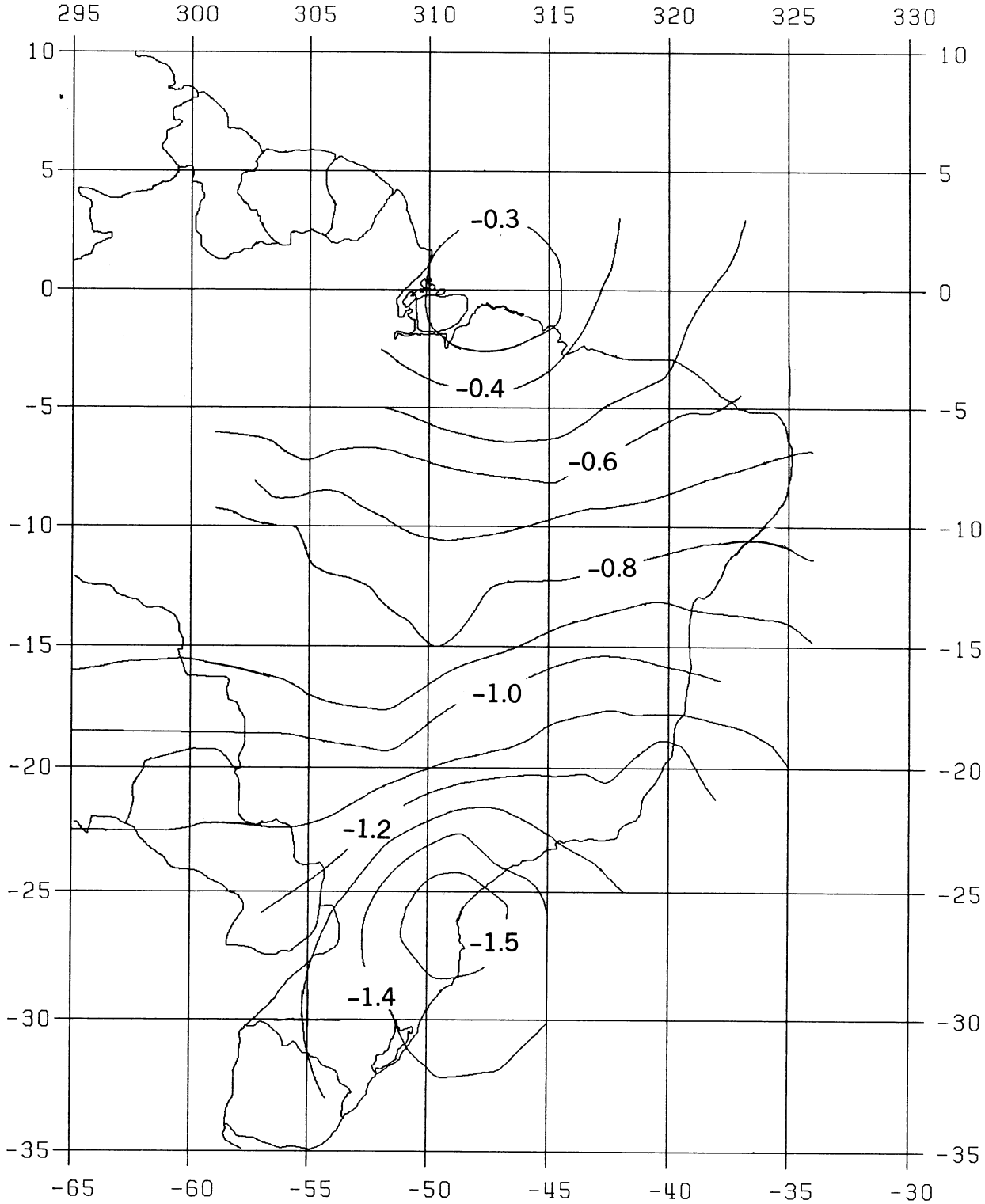

Figure 16.28. Contour Chart – Latitude Differences, WGS 84 Minus Corrego Alegre Datum (Contour Interval = 0.1 Arc Second)

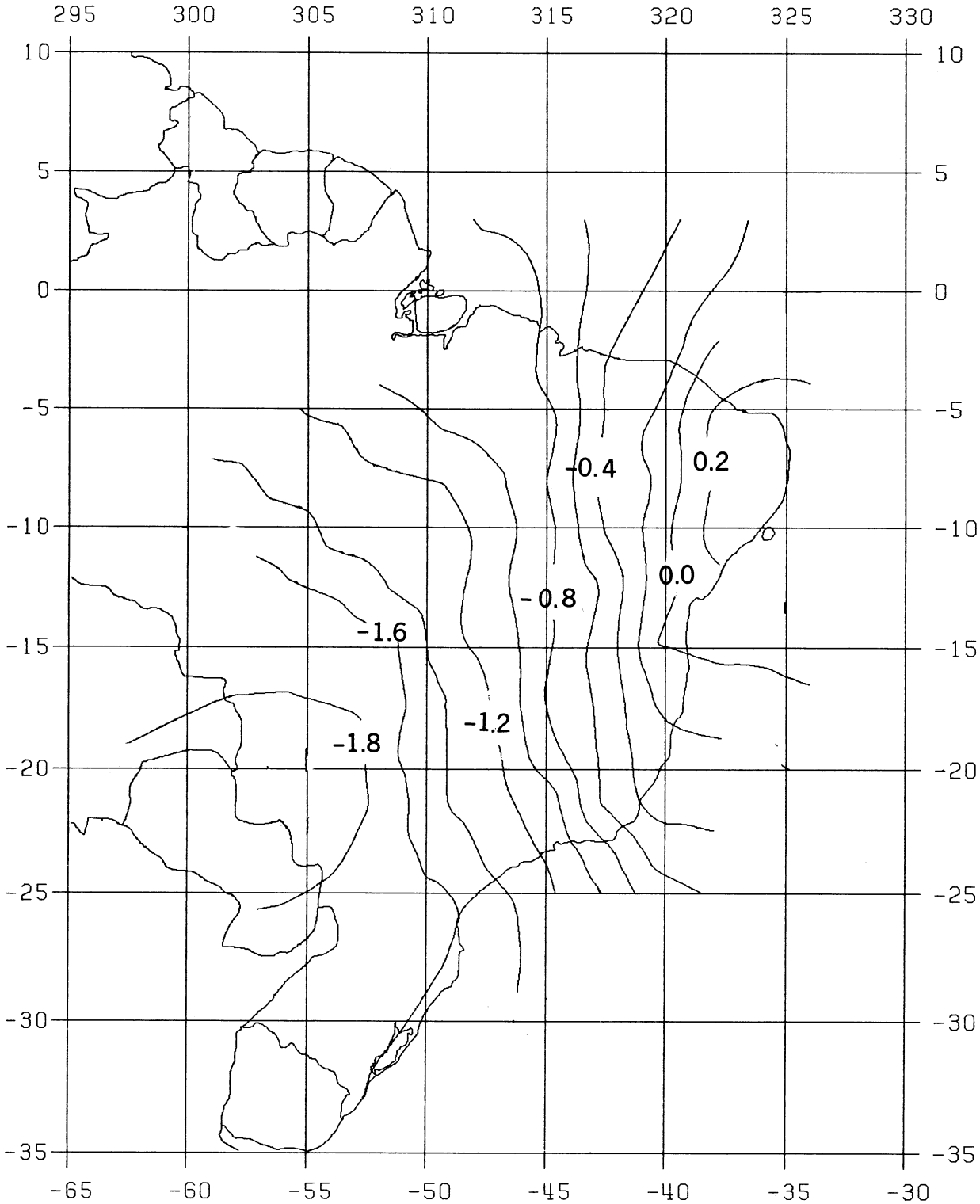

Figure 16.29. Contour Chart – Longitude Differences, WGS 84 Minus Corrego Alegre Datum (Contour Interval = 0.2 Arc Second)

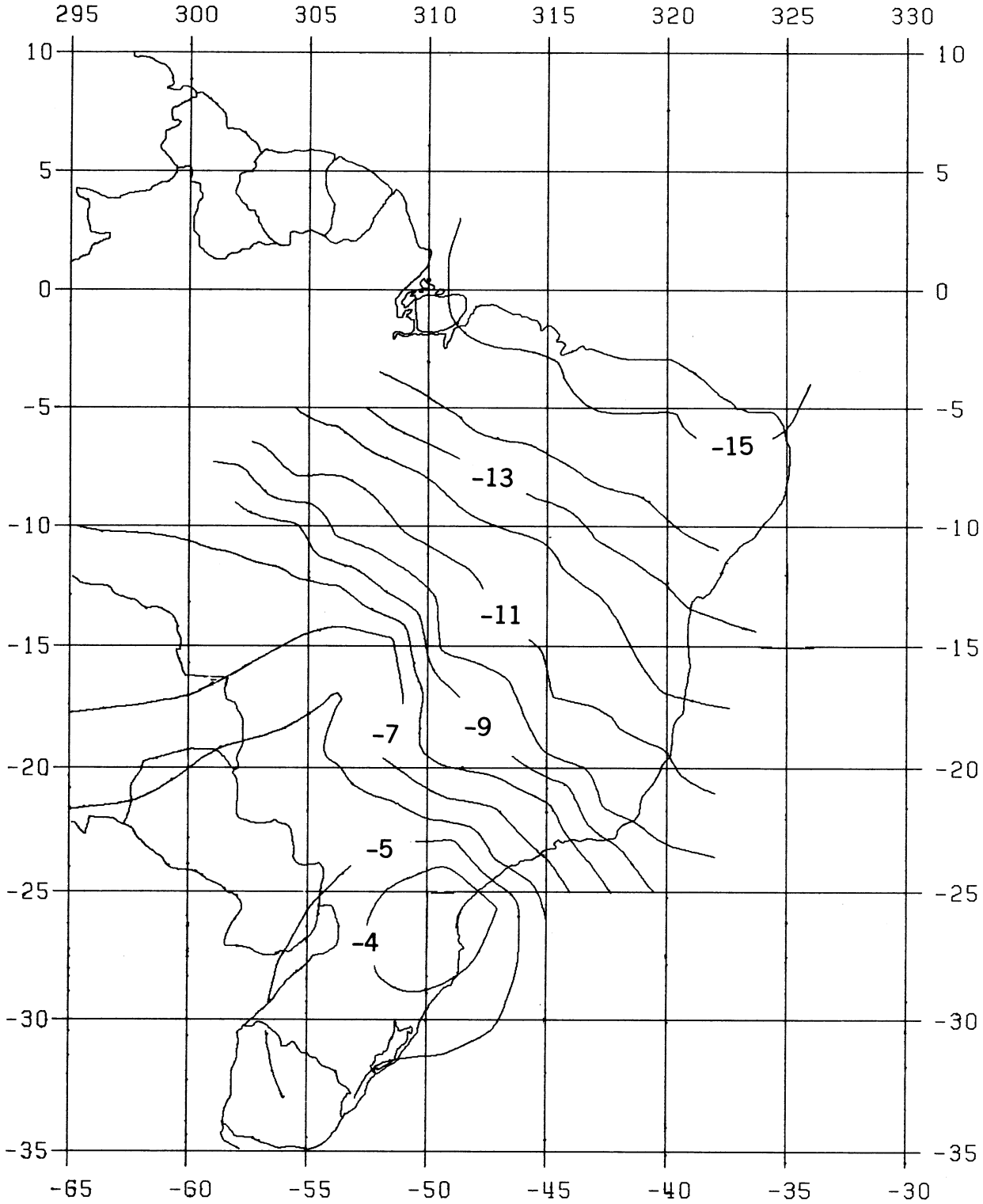

Figure 16.30. Contour Chart - Geodetic Height Differences, WGS 84 Minus Corrego Alegre Datum (Contour Interval = 1 Meter)

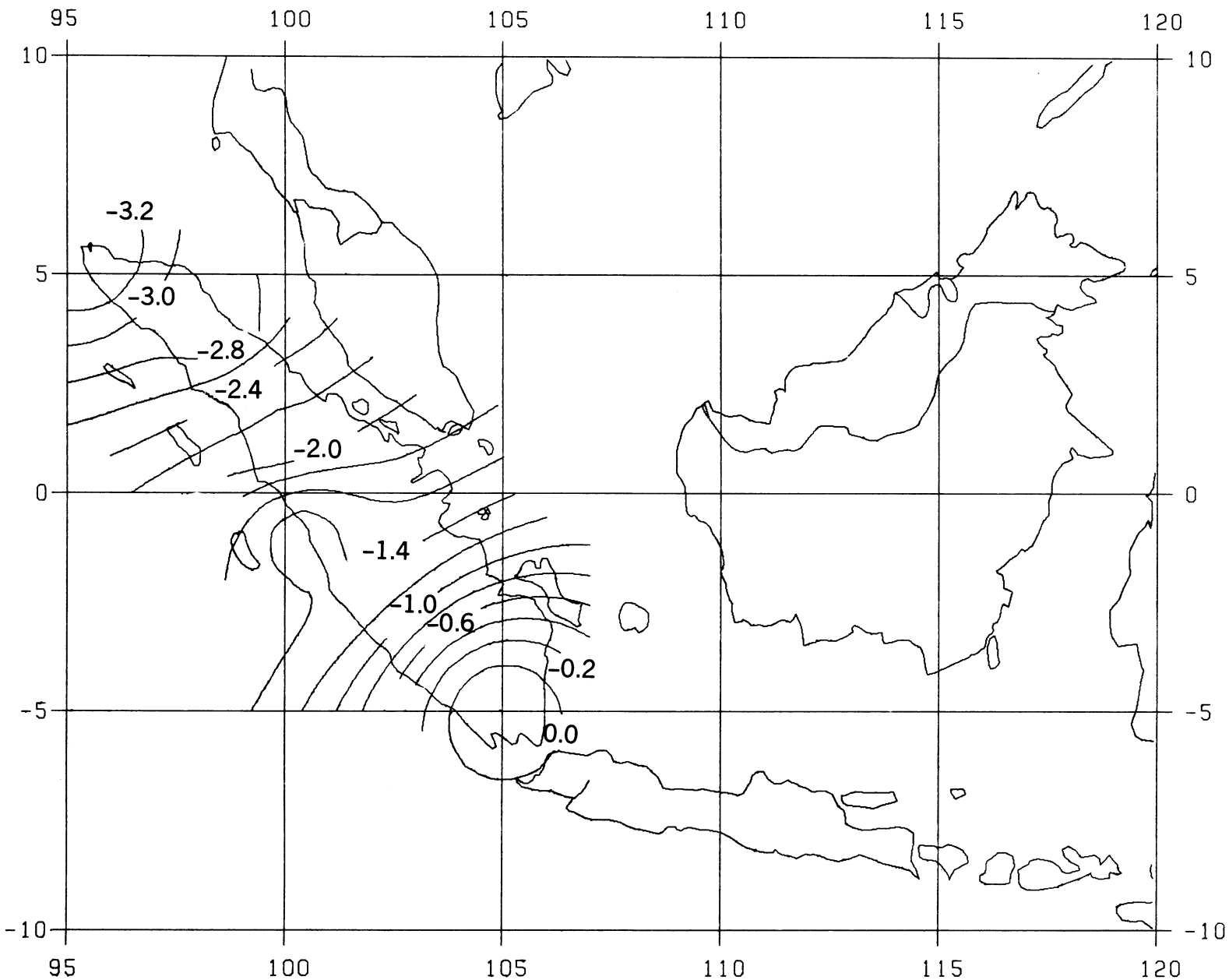

Figure 16.31. Contour Chart - Latitude Differences, WGS 84 Minus Djakarta Datum (Contour Interval = 0.2 Arc Second)

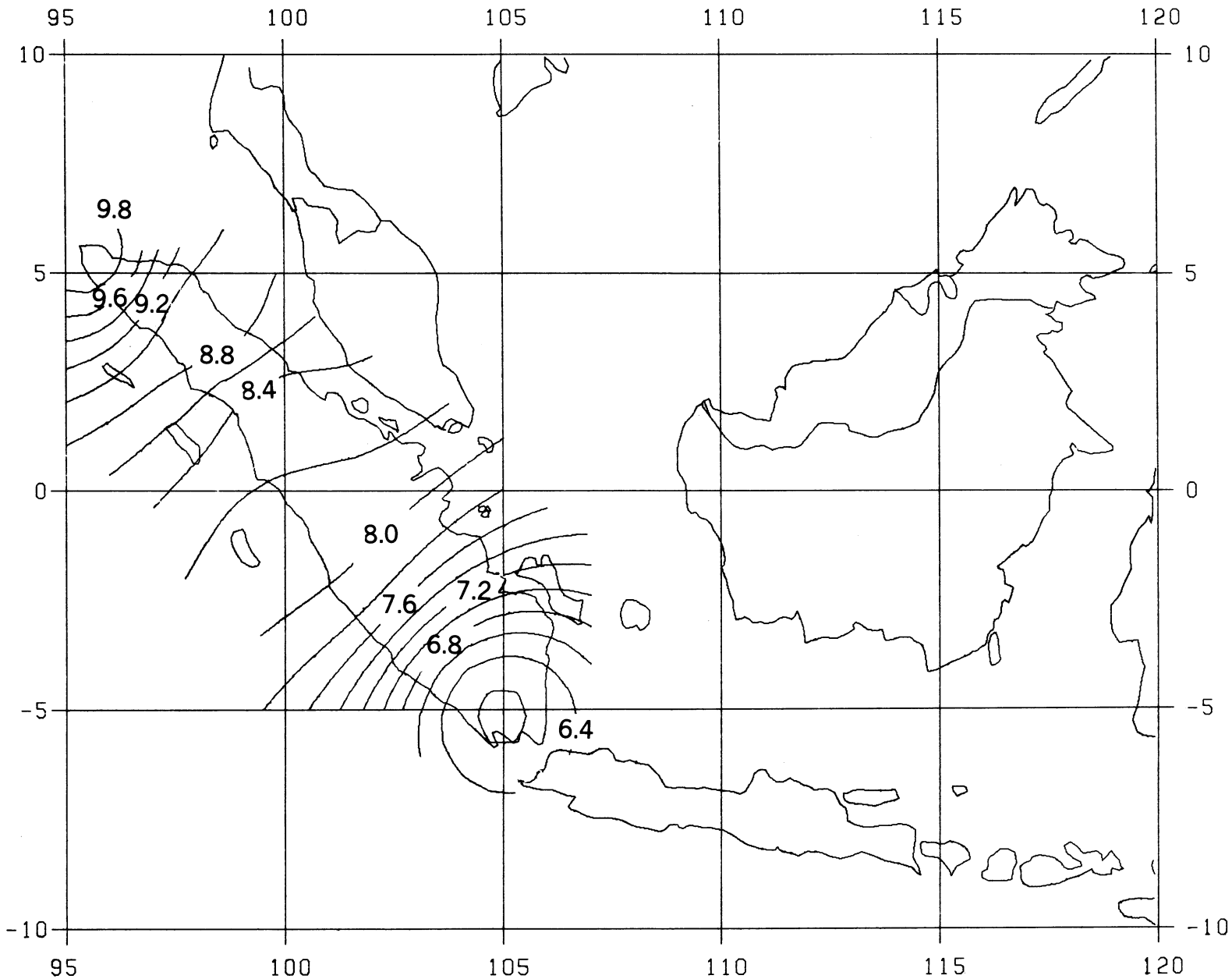

Figure 16.32. Contour Chart - Longitude Differences, WGS 84 Minus Djakarta Datum (Contour Interval = 0.2 Arc Second)

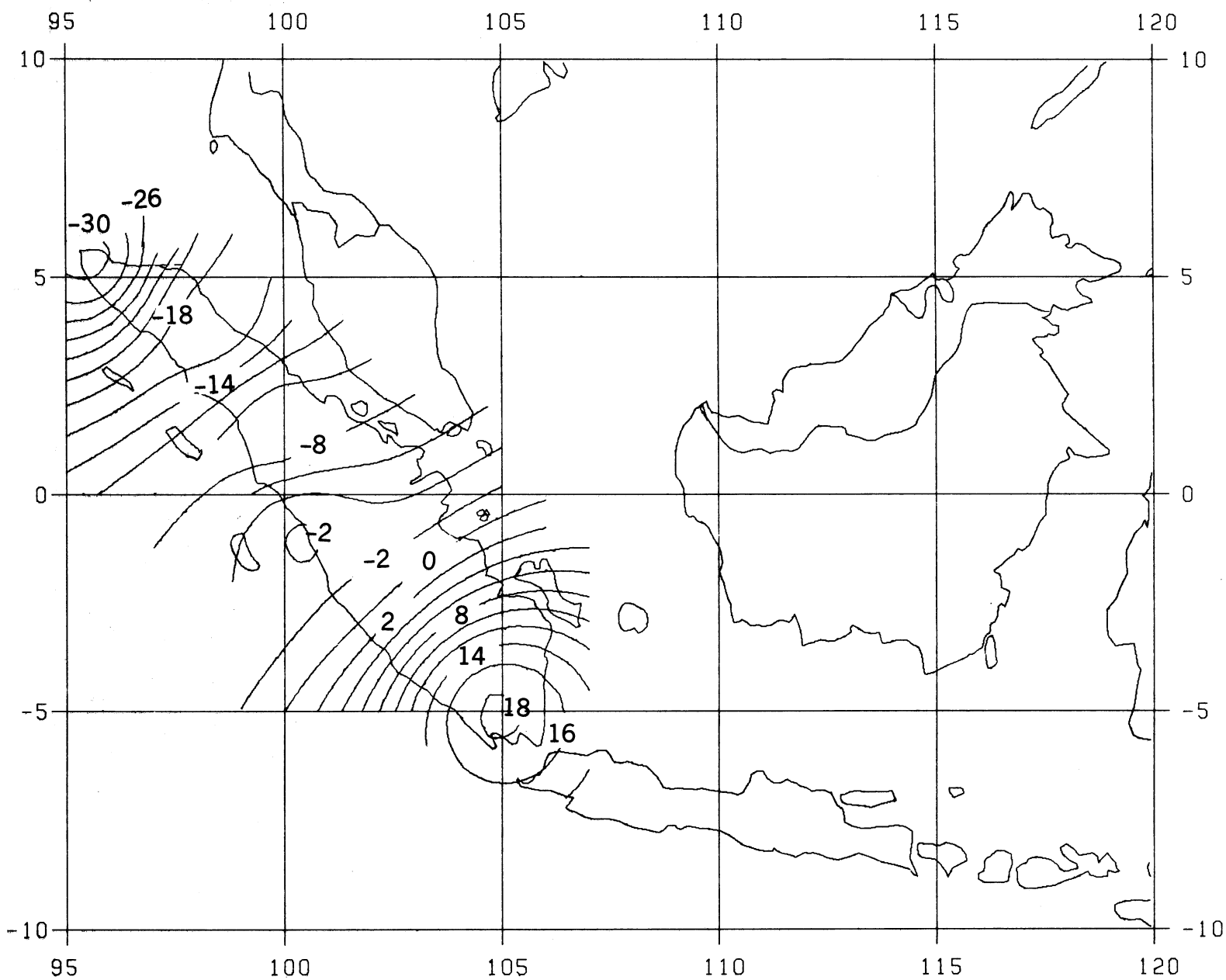

Figure 16.33. Contour Chart - Geodetic Height Differences, WGS 84 Minus Djakarta Datum (Contour Interval = 2 Meters)

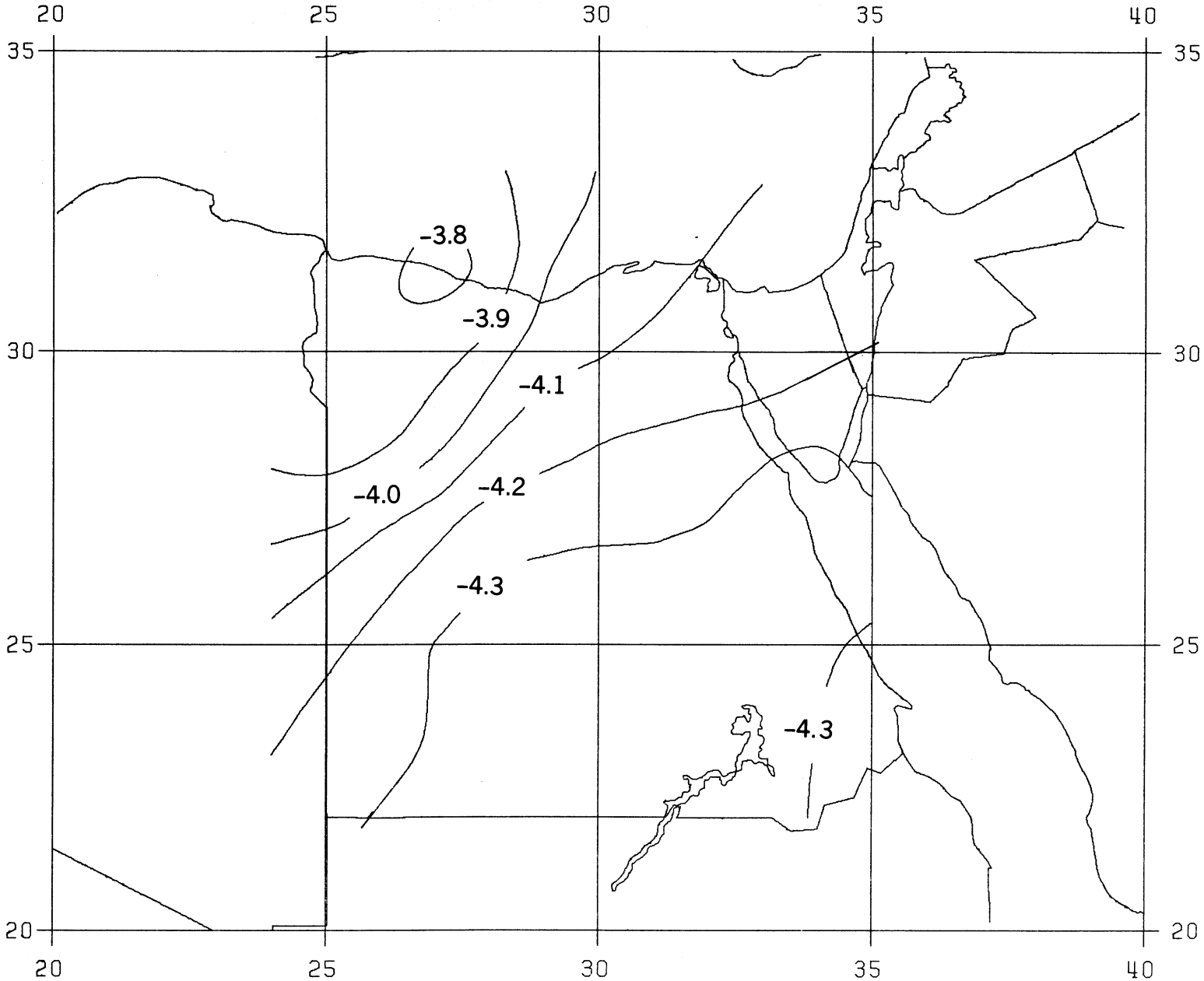

Figure 16.34. Contour Chart - Latitude Differences, WGS 84 Minus ED 50 (Egypt) (Contour Interval = 0.1 Arc Second)

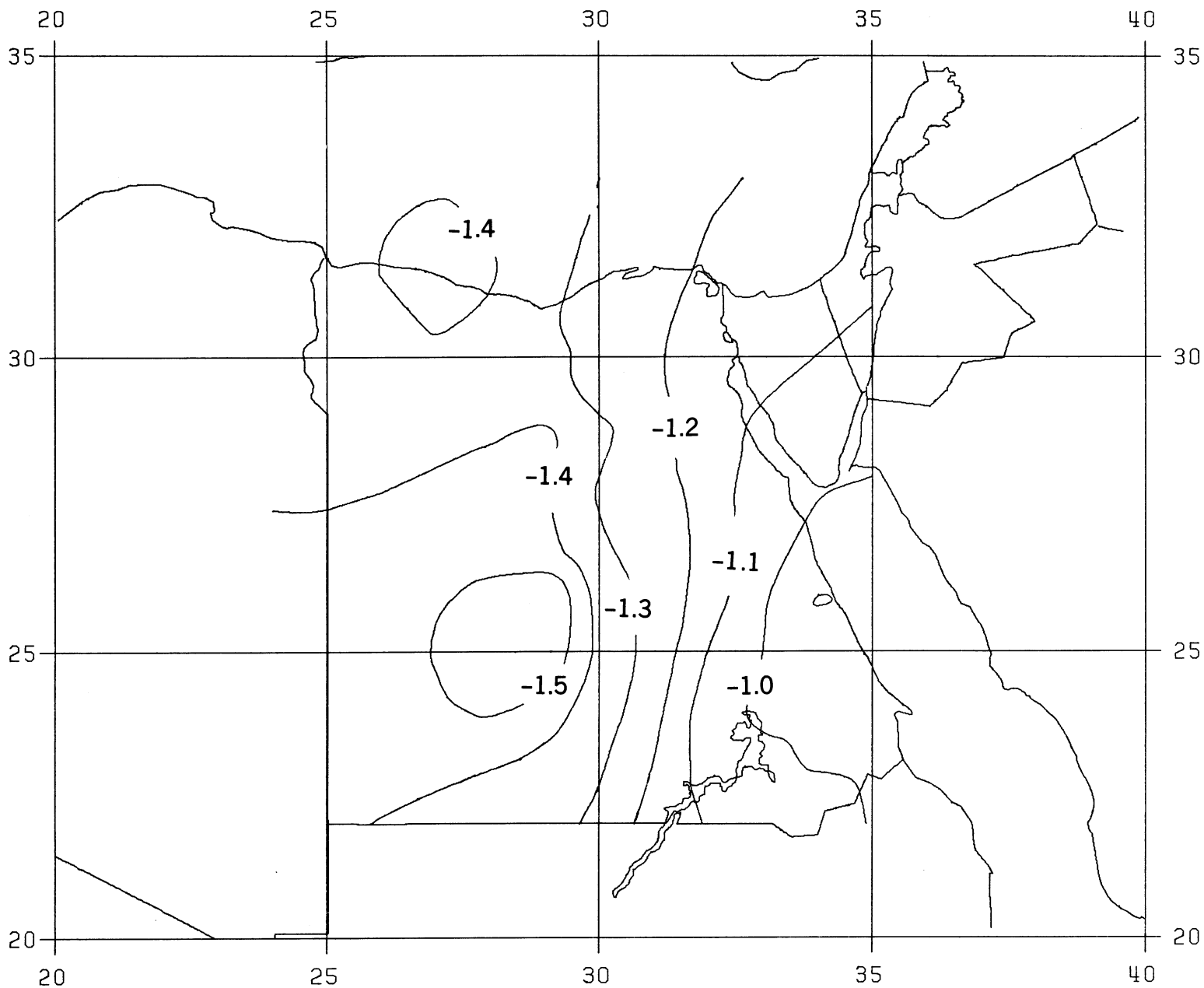

Figure 16.35. Contour Chart - Longitude Differences, WGS 84 Minus ED 50 (Egypt)(Contour Interval = 0.1 Arc Second)

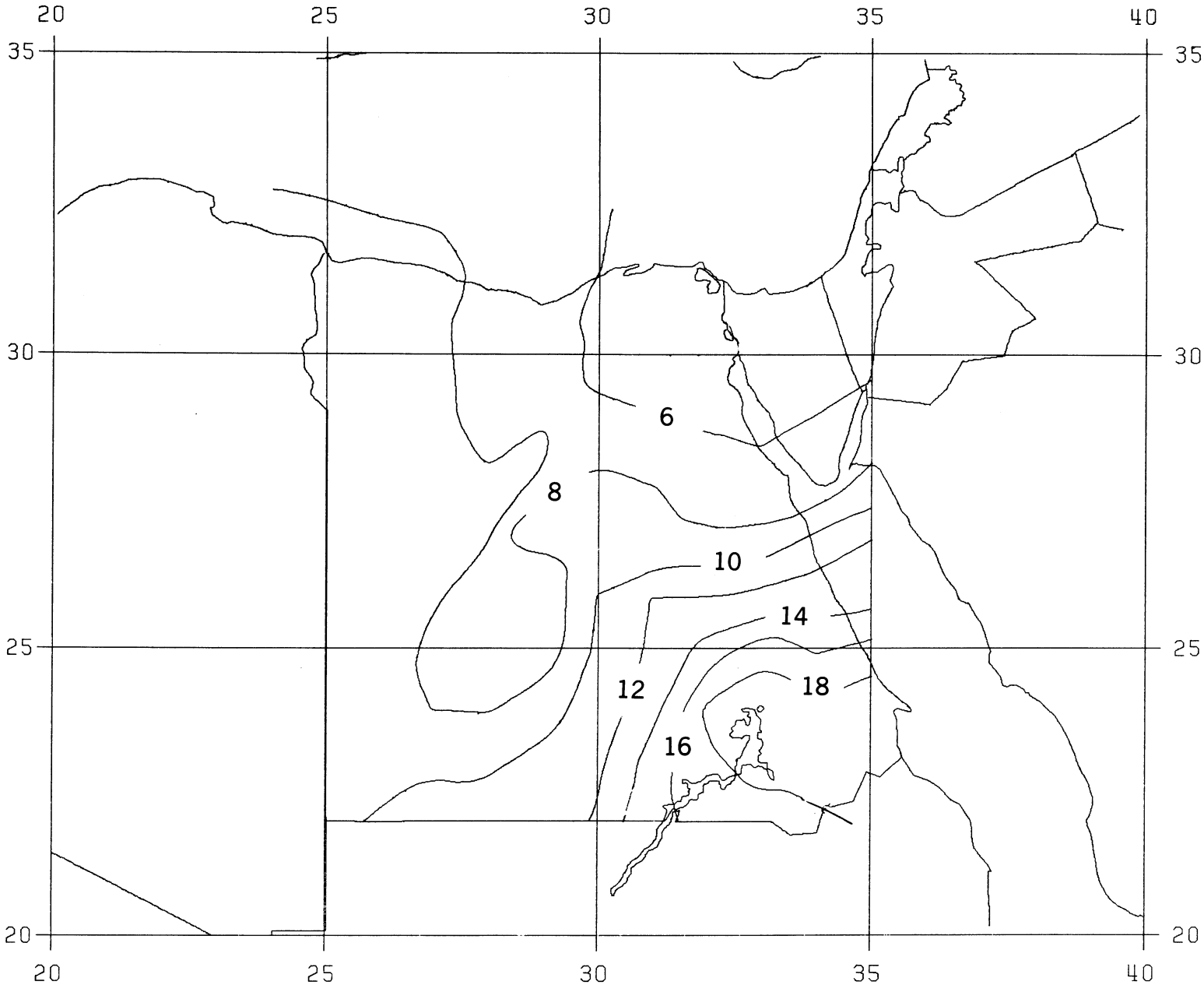

Figure 16.36. Contour Chart - Geodetic Height Differences, WGS 84 Minus ED 50 (Egypt) (Contour Interval = 2 Meters)

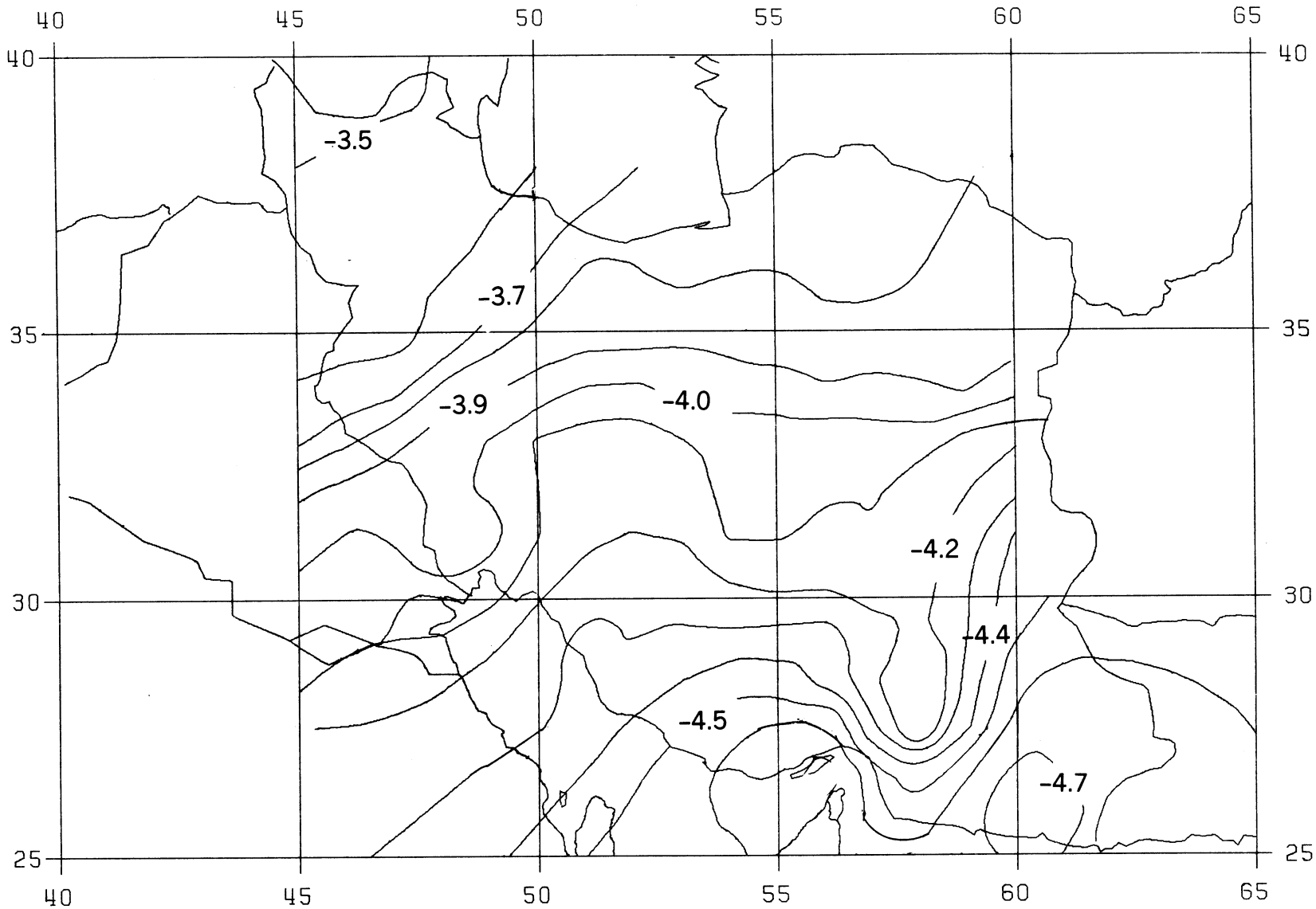

Figure 16.37. Contour Chart - Latitude Differences, WGS 84 Minus ED 50 (Iran) (Contour Interval = 0.1 Arc Second)

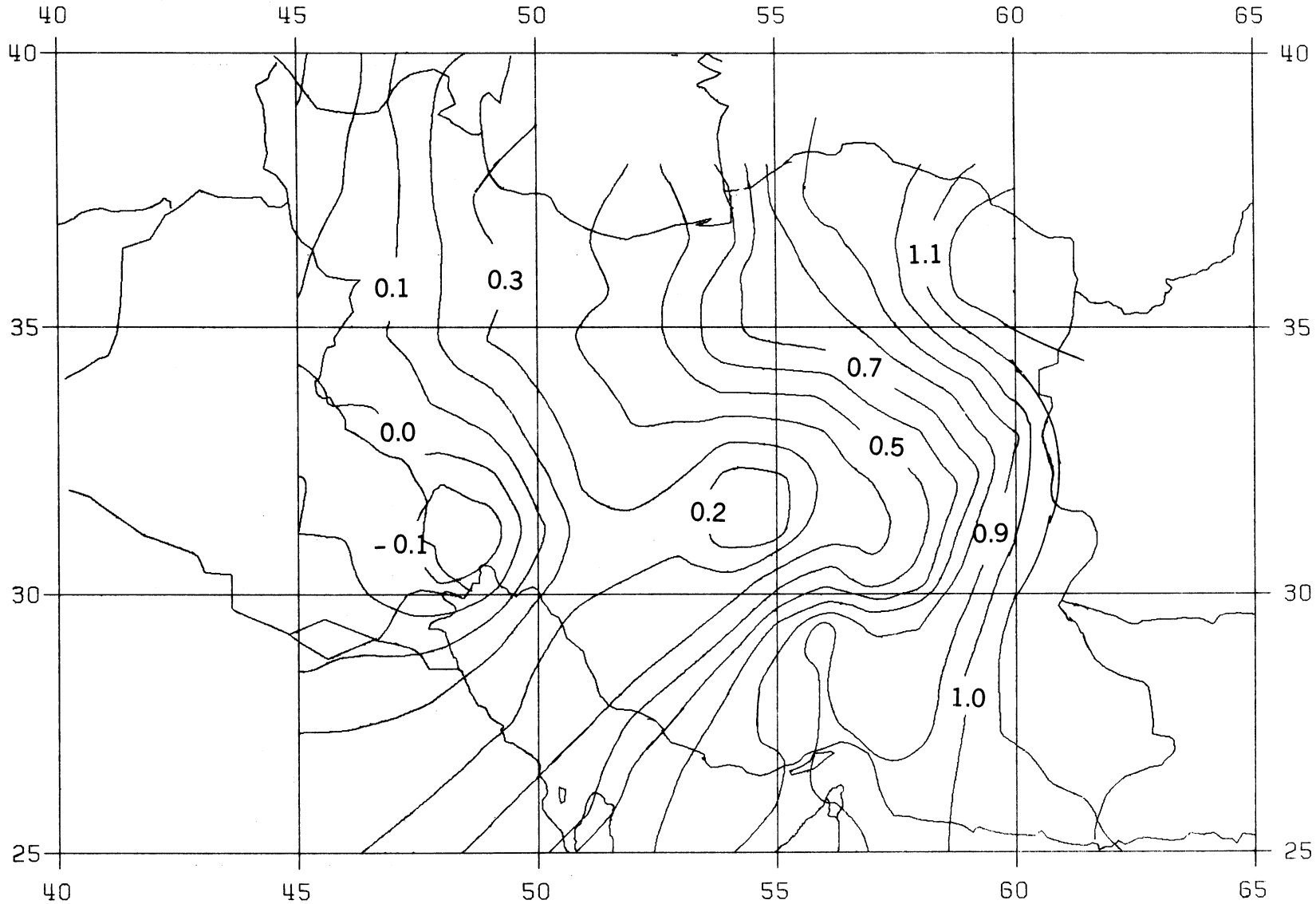

Figure 16.38. Contour Chart – Longitude Differences, WGS 84 Minus ED 50 (Iran) (Contour Interval = 0.1 Arc Second)

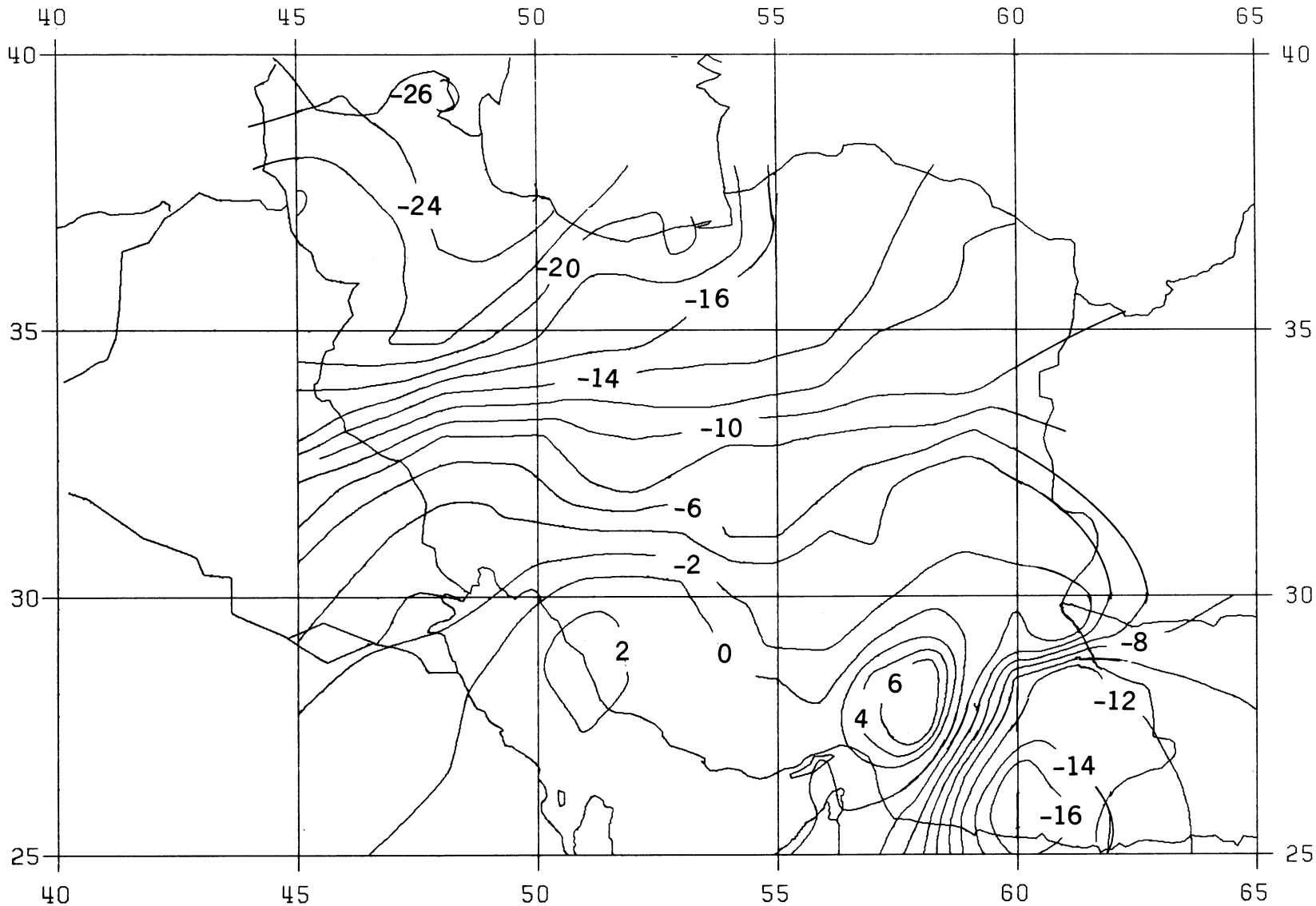

Figure 16.39. Contour Chart - Geodetic Height Differences, WGS 84 Minus ED 50 (Iran) (Contour Interval = 2 Meters)

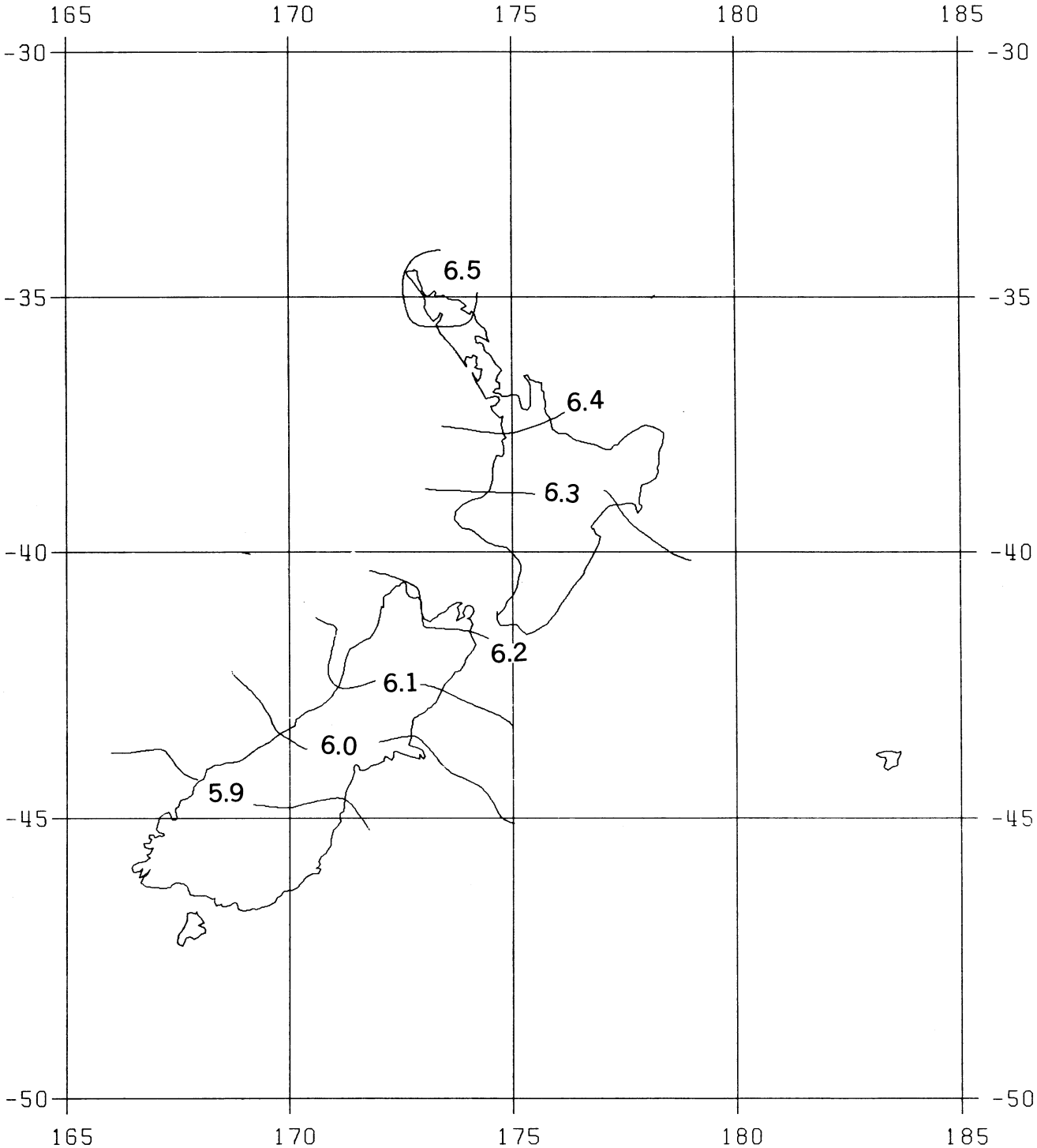

Figure 16.40. Contour Chart - Latitude Differences, WGS 84 Minus Geodetic Datum 1949 (Contour Interval = 0.1 Arc Second)

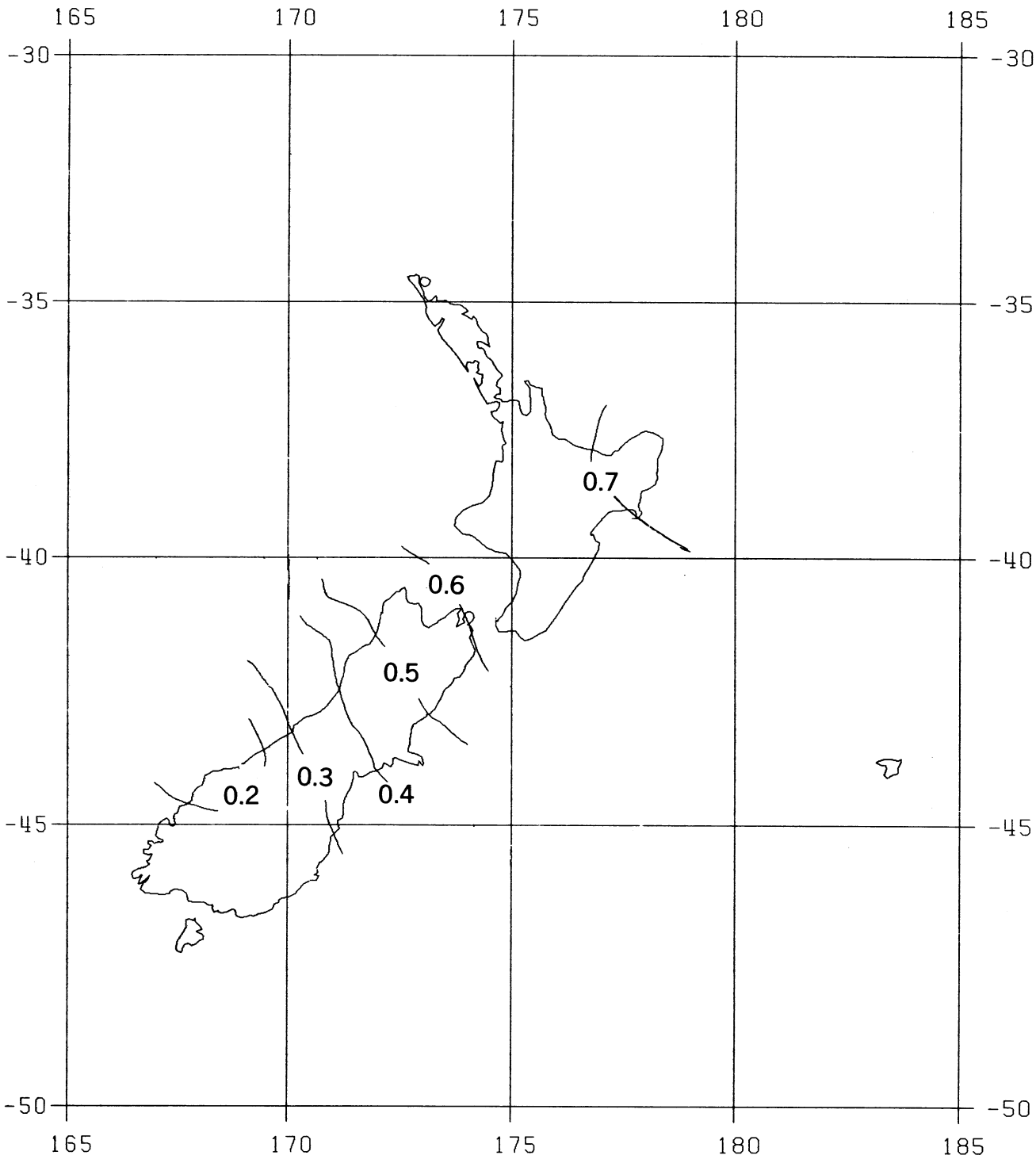

Figure 16.41. Contour Chart – Longitude Differences, WGS 84 Minus Geodetic Datum 1949 (Contour Interval = 0.1 Arc Second)

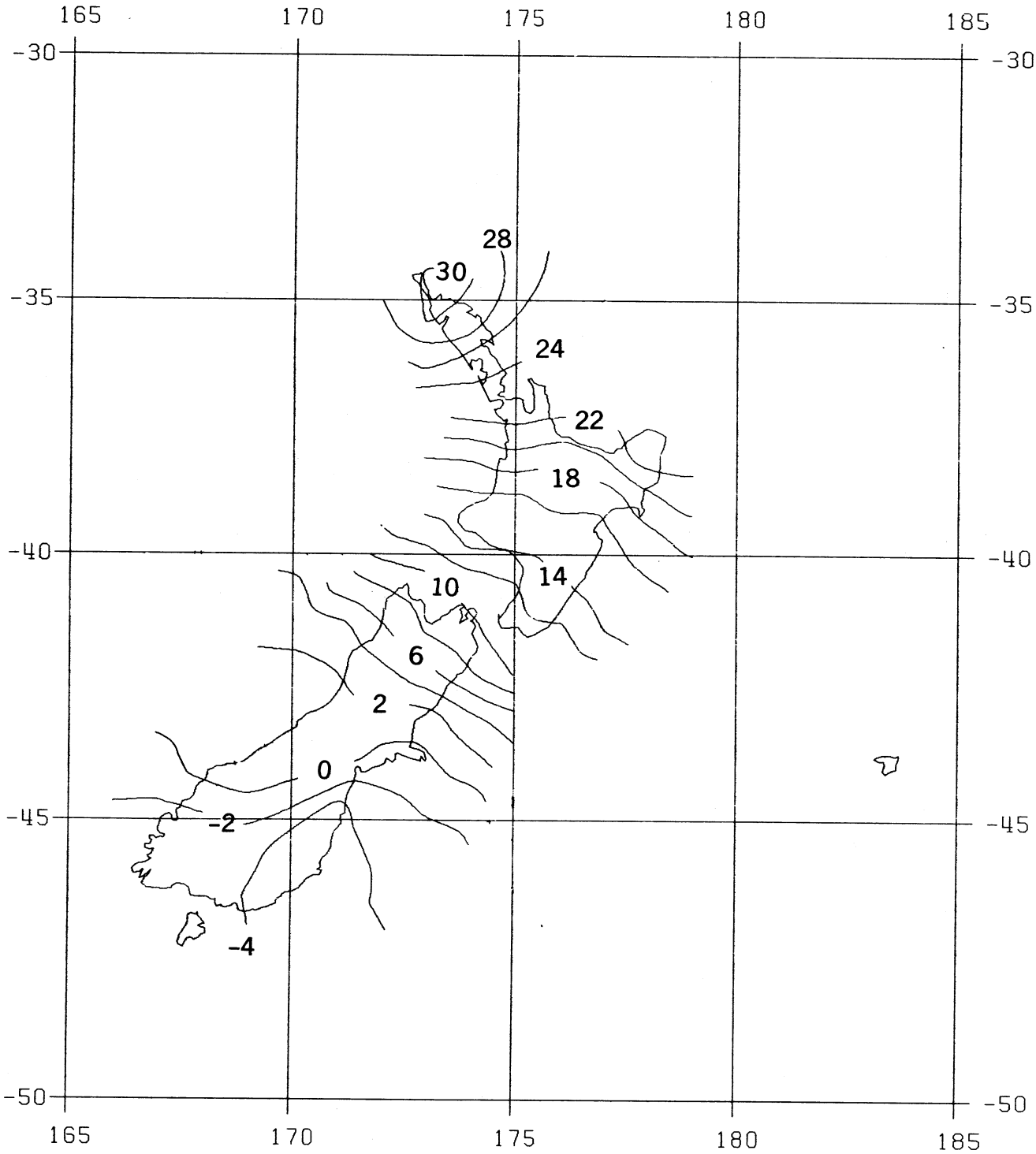

Figure 16.42. Contour Chart - Geodetic Height Differences, WGS 84 Minus Geodetic Datum 1949 (Contour Interval = 2 Meters)

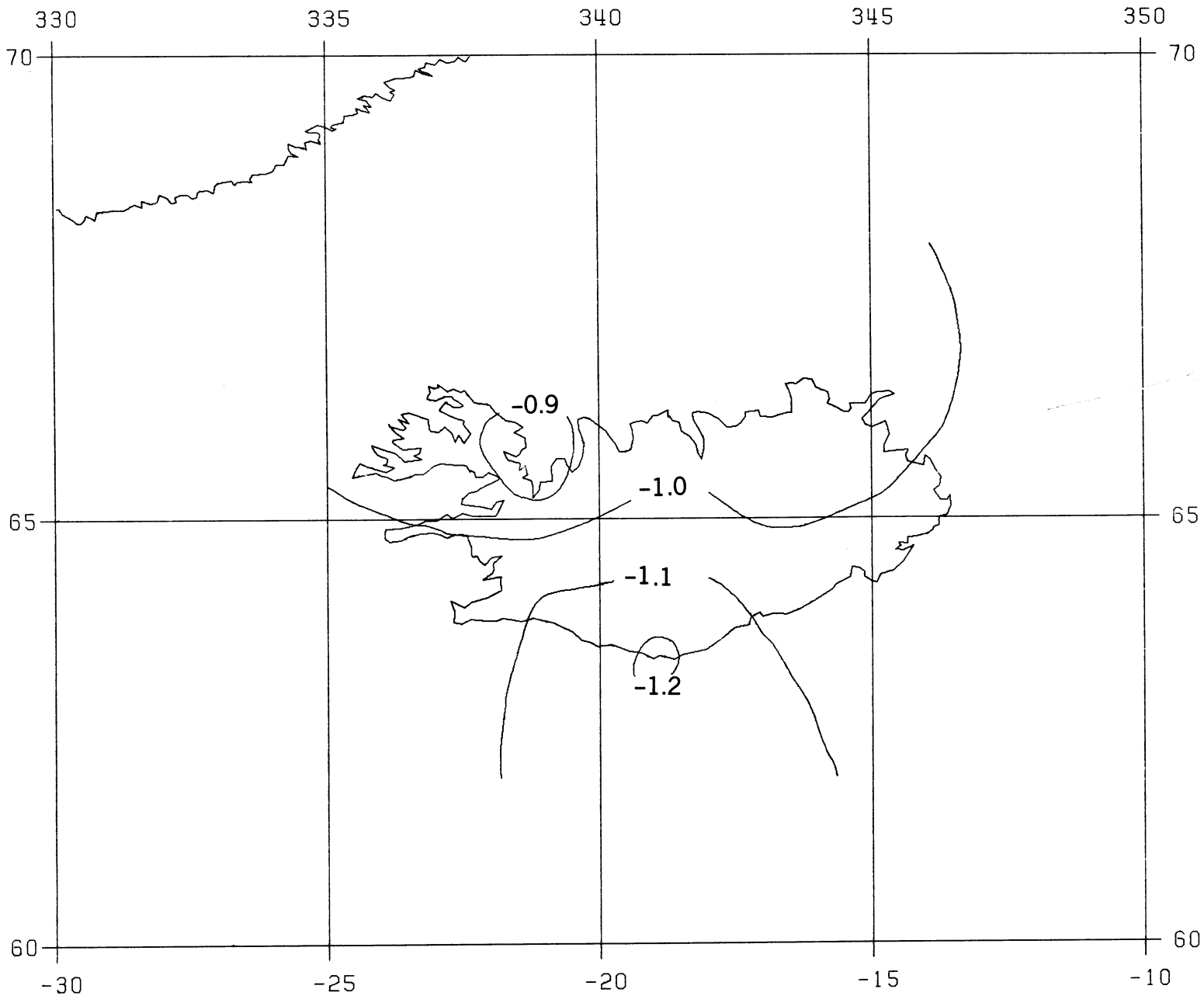

Figure 16.43. Contour Chart – Latitude Differences, WGS 84 Minus Hjorsey Datum 1955 (Contour Interval = 0.1 Arc Second)

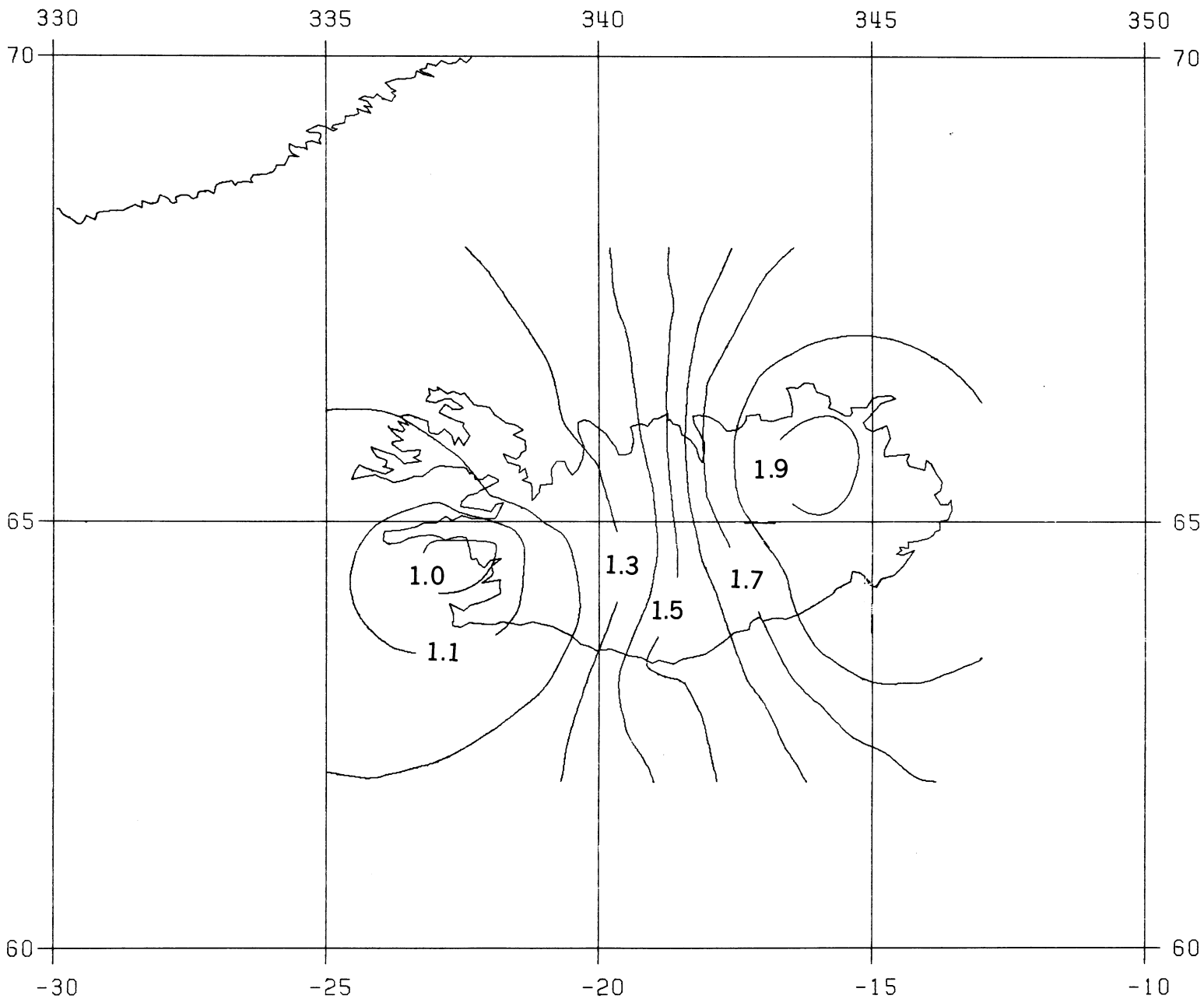

Figure 16.44. Contour Chart - Longitude Differences, WGS 84 Minus Hjorsey Datum 1955 (Contour Interval = 0.1 Arc Second)

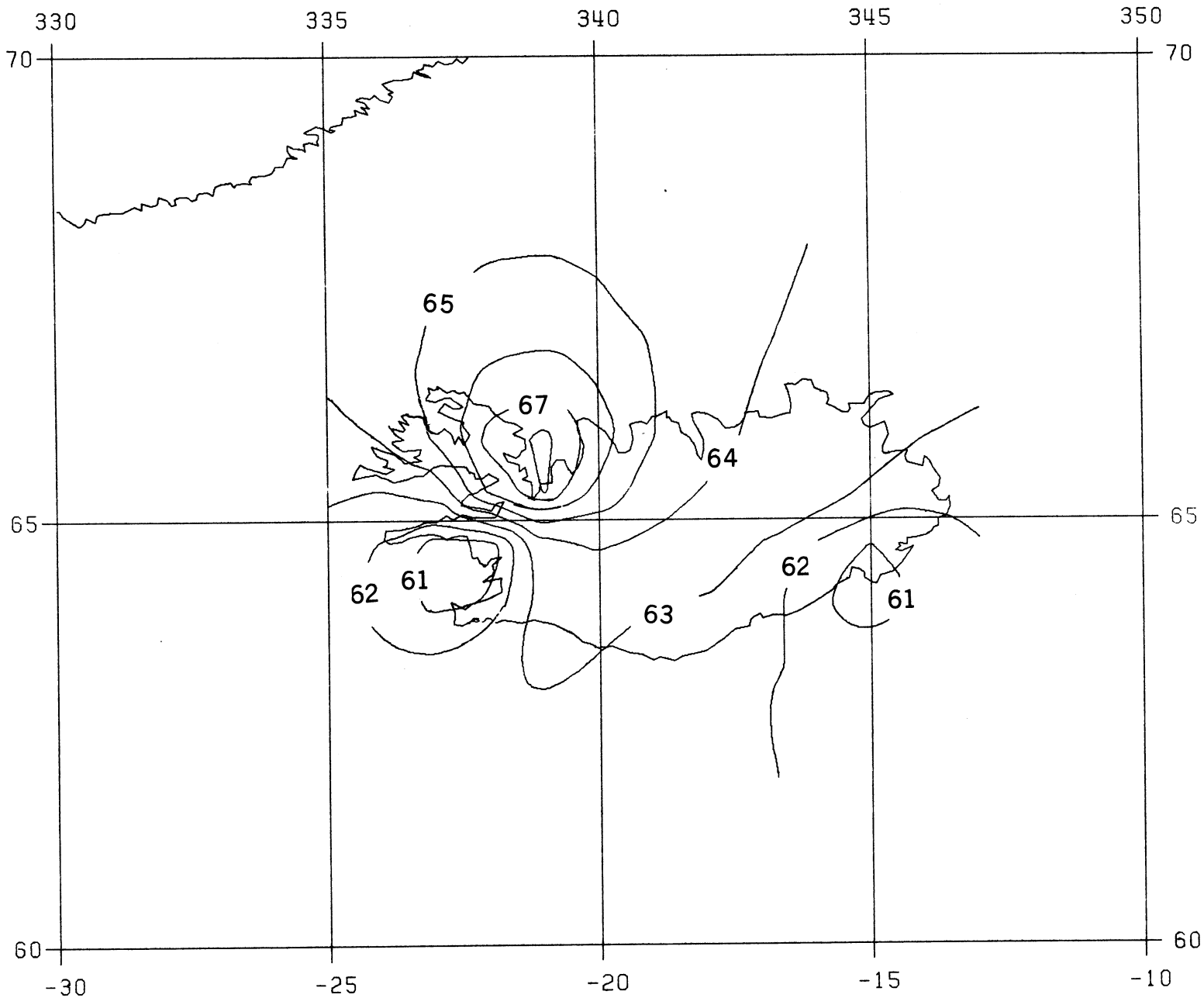

Figure 16.45. Contour Chart – Geodetic Height Differences, WGS 84 Minus Hjorsey Datum 1955 (Contour Interval = 1 Meter)

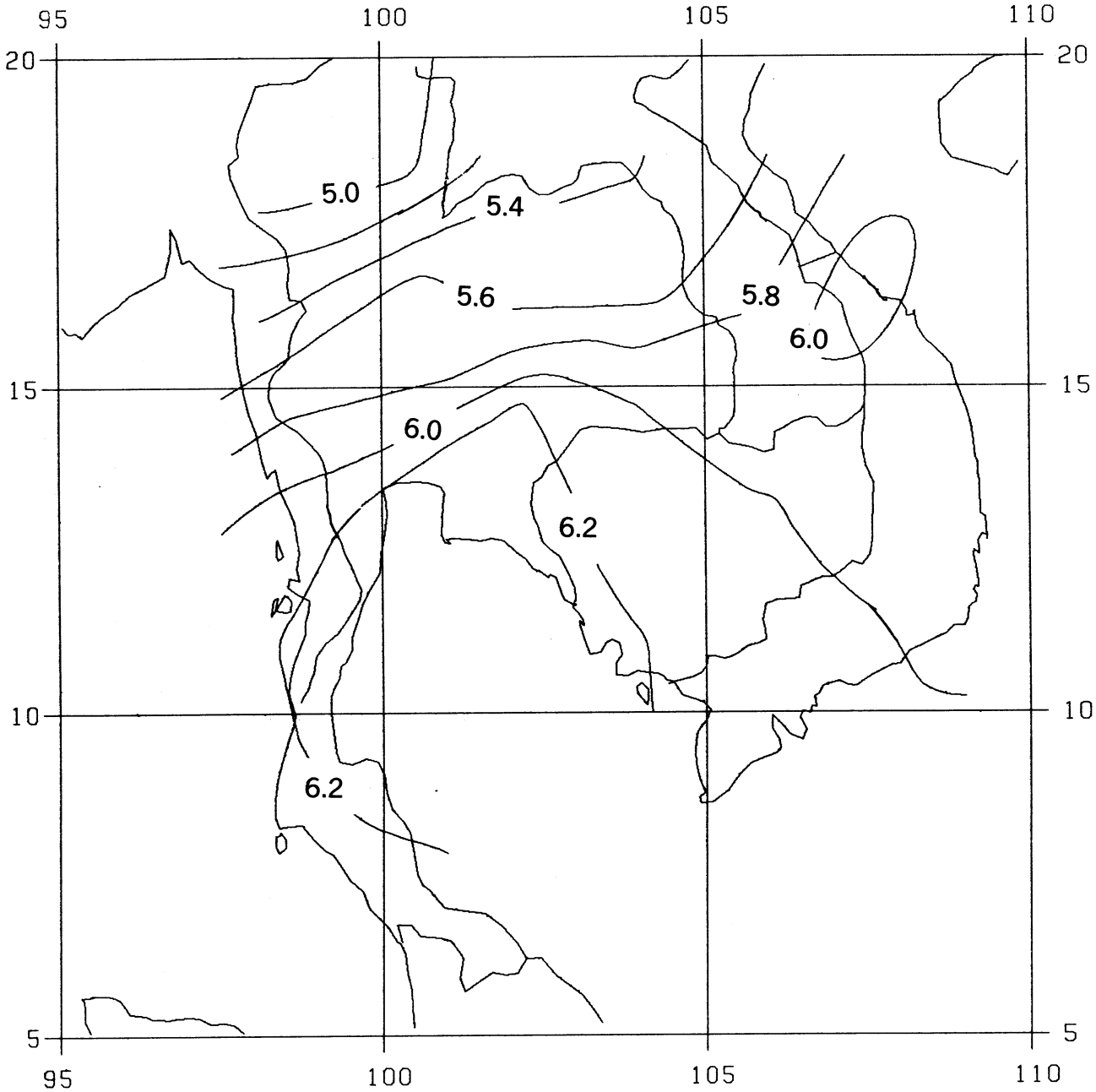

Figure 16.46. Contour Chart - Latitude Differences, WGS 84 Minus Indian Datum
(Contour Interval = 0.2 Arc Second)

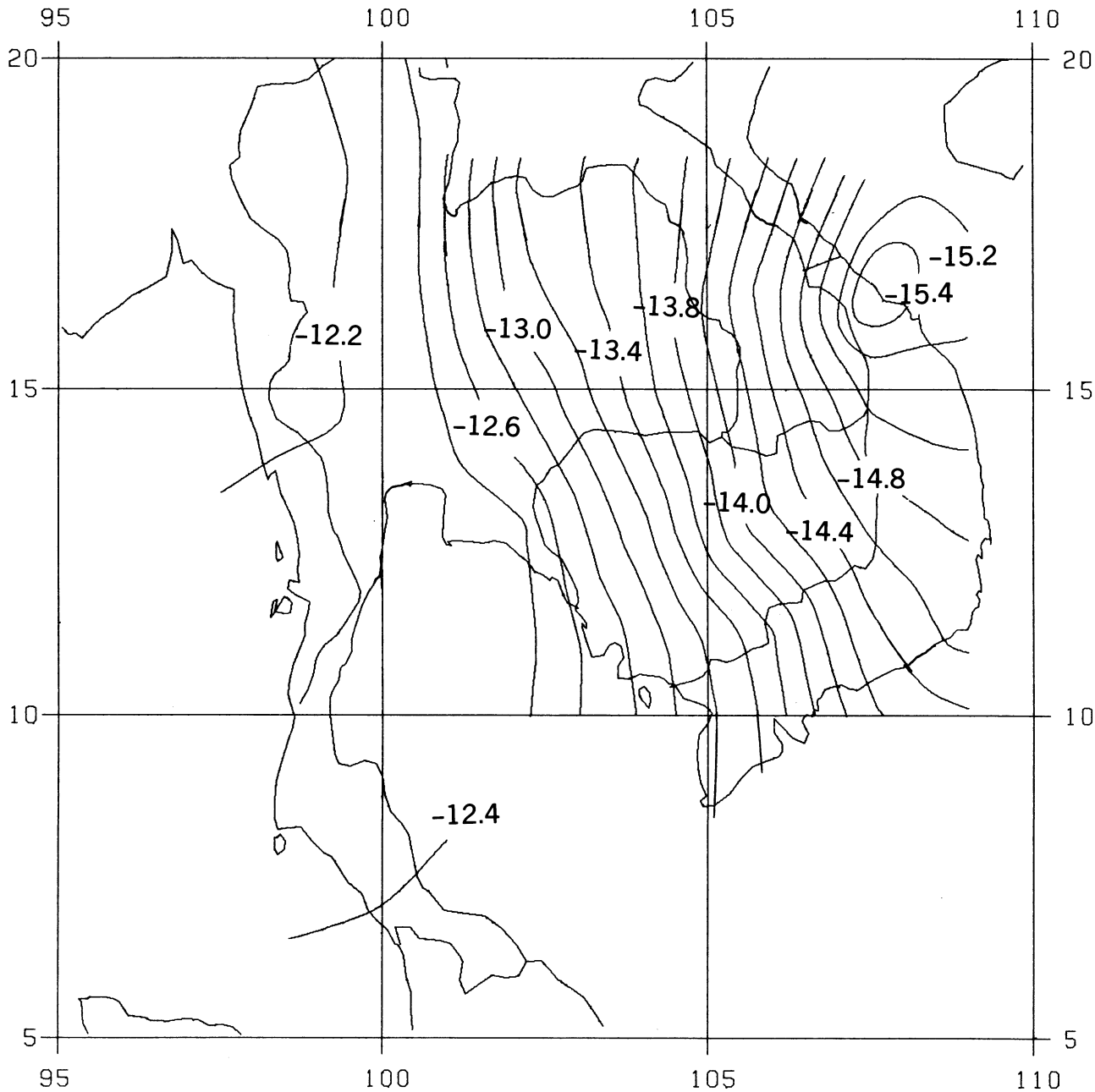

Figure 16.47. Contour Chart – Longitude Differences, WGS 84 Minus Indian Datum (Contour Interval = 0.2 Arc Second)

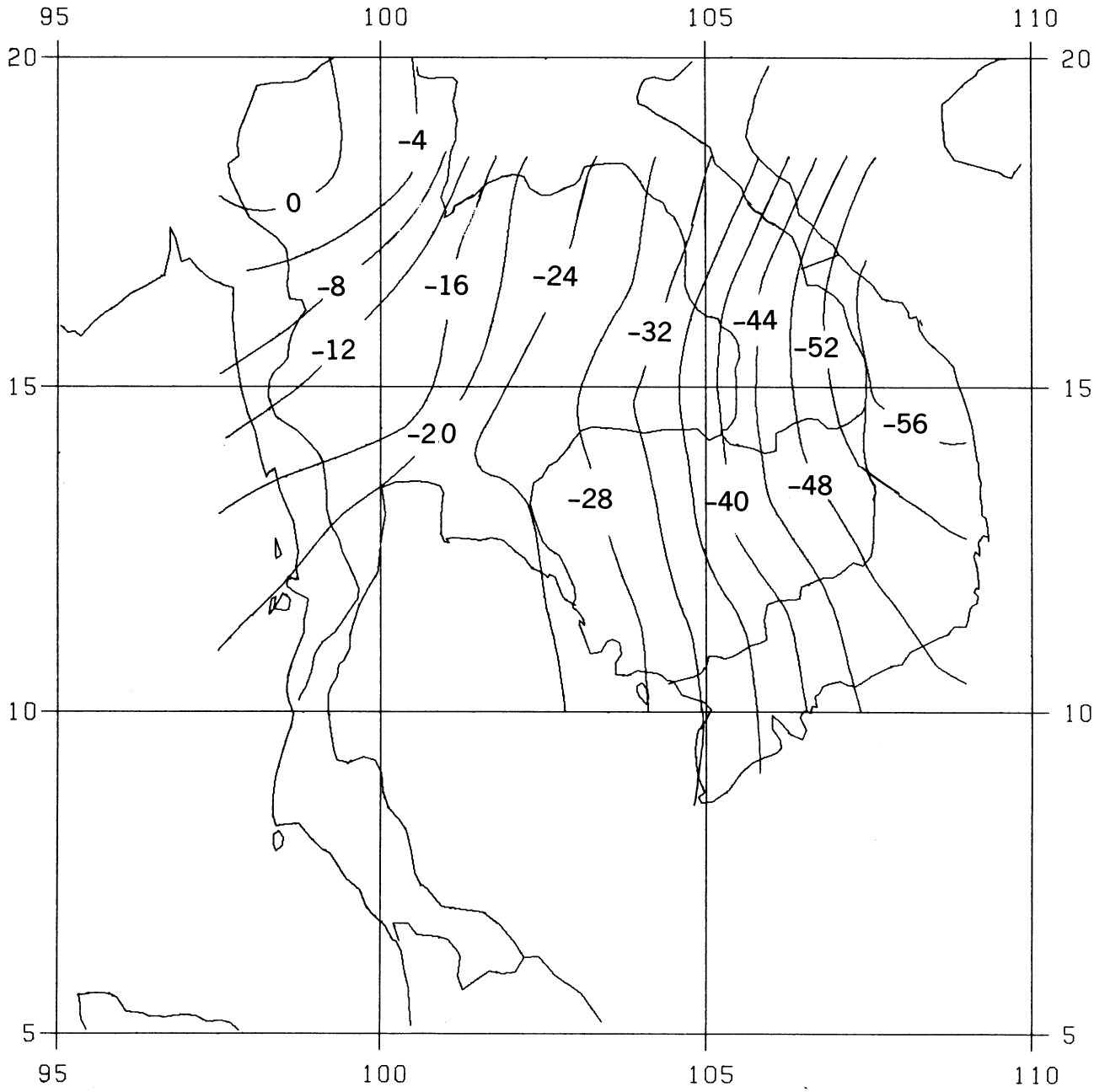

Figure 16.48. Contour Chart - Geodetic Height Differences, WGS 84 Minus Indian Datum (Contour Interval = 4 Meters)

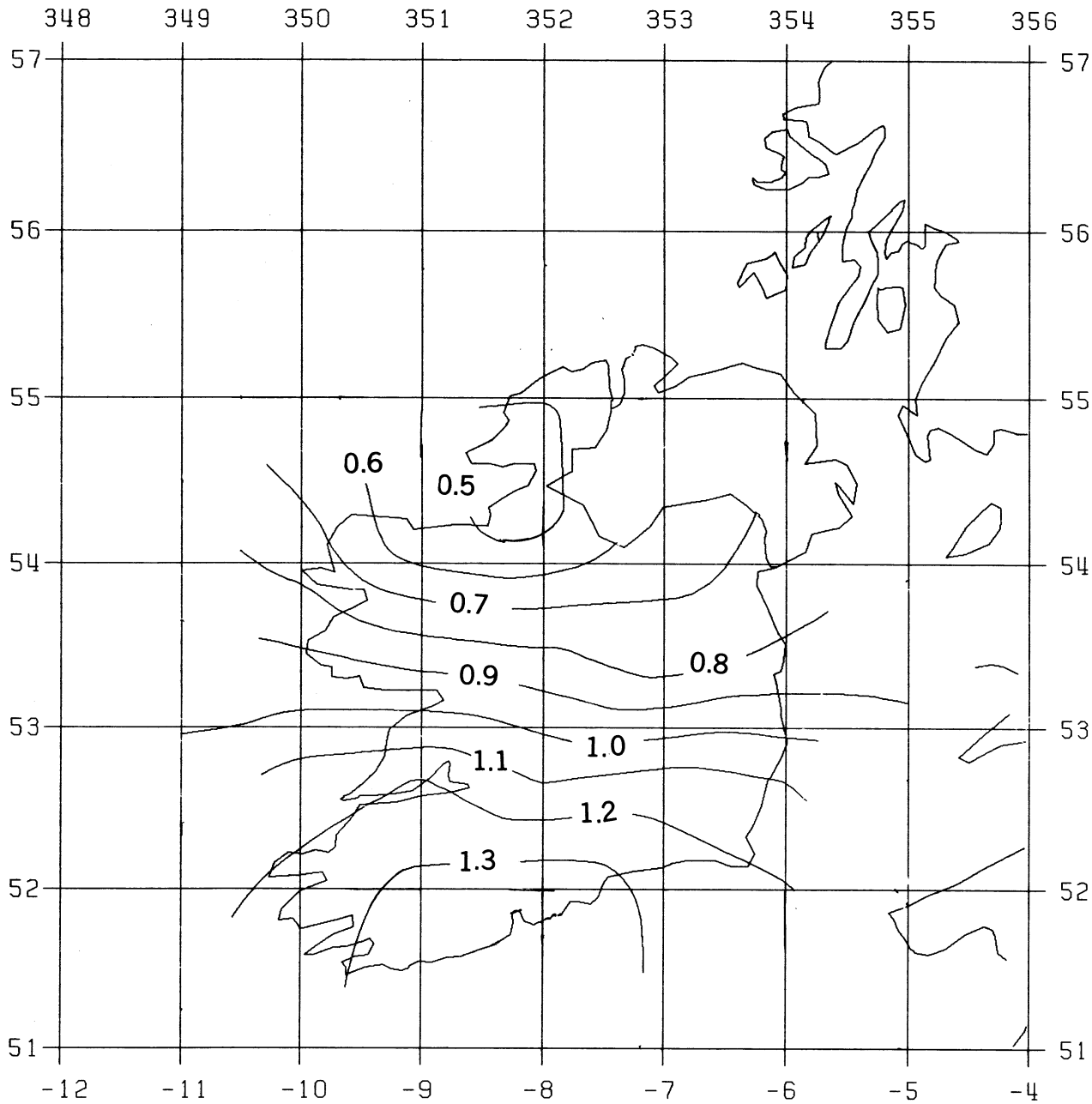

Figure 16.49. Contour Chart - Latitude Differences, WGS 84 Minus Ireland Datum 1965 (Contour Interval = 0.1 Arc Second)

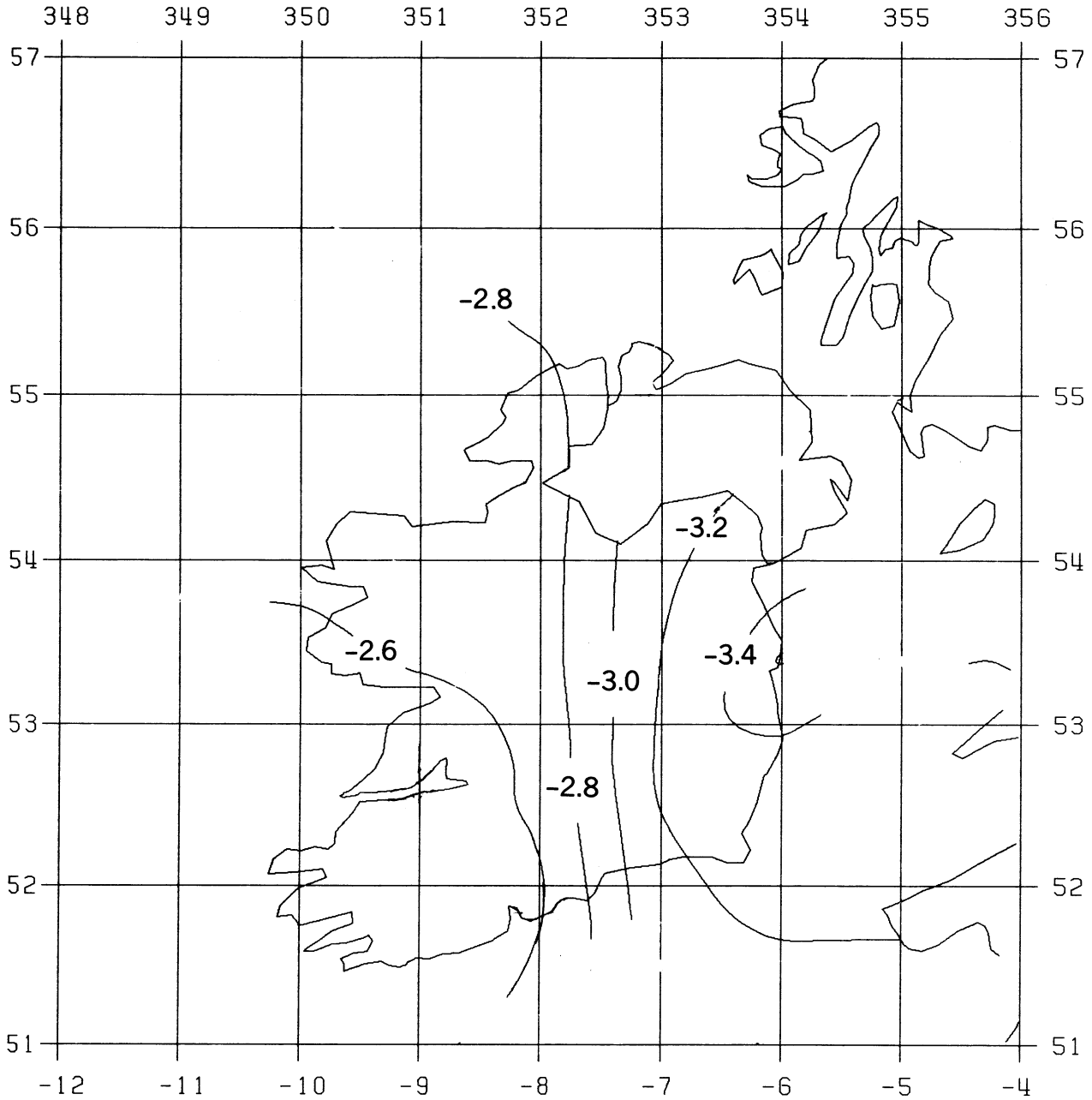

Figure 16.50. Contour Chart - Longitude Differences, WGS 84 Minus Ireland Datum 1965
(Contour Interval = 0.2 Arc Second)

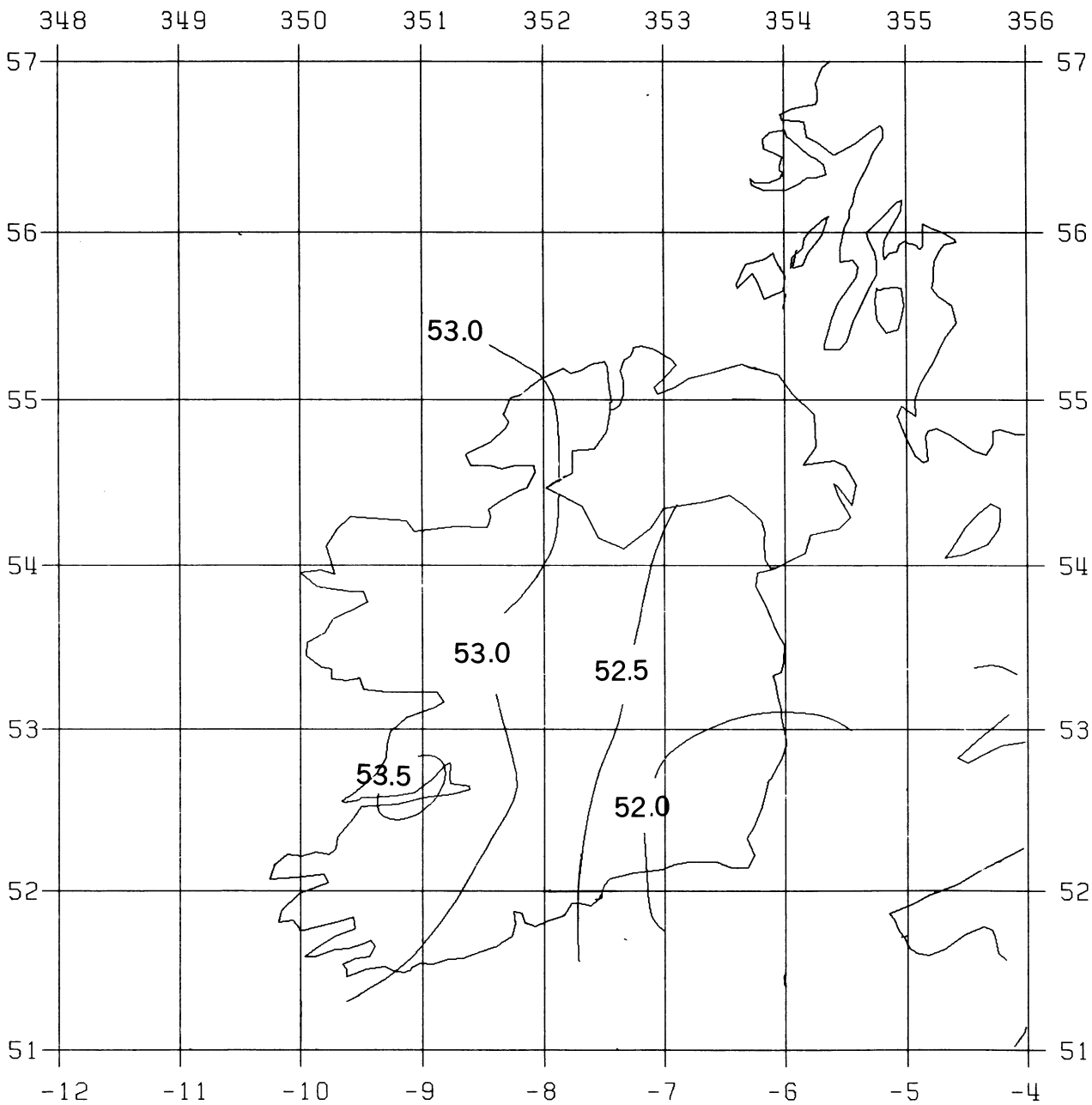

Figure 16.51. Contour Chart - Geodetic Height Differences, WGS 84 Minus Ireland Datum 1965 (Contour Interval = 0.5 Meter)

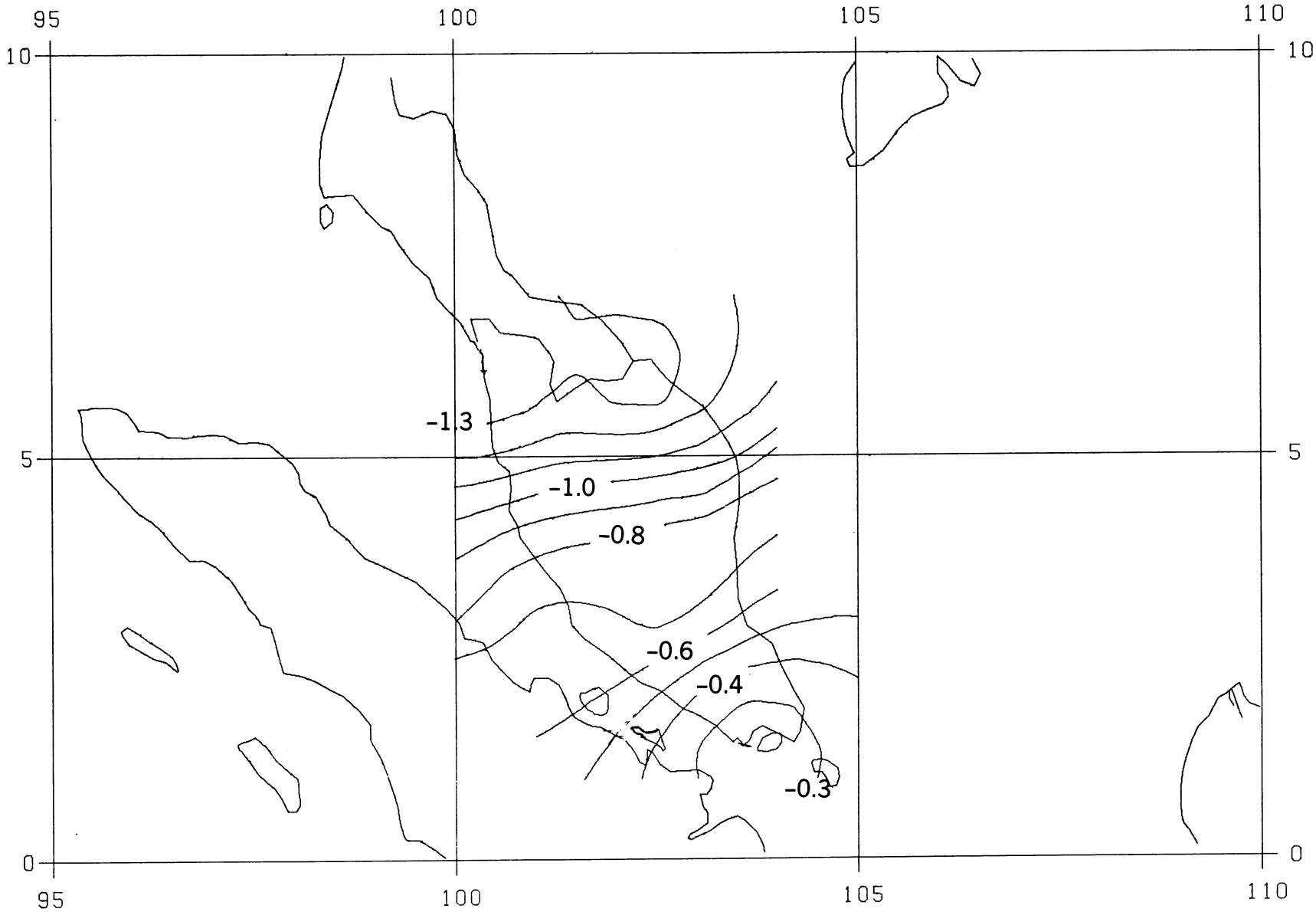

Figure 16.52. Contour Chart - Latitude Differences, WGS 84 Minus Kertau Datum 1948 (Contour Interval = 0.1 Arc Second)

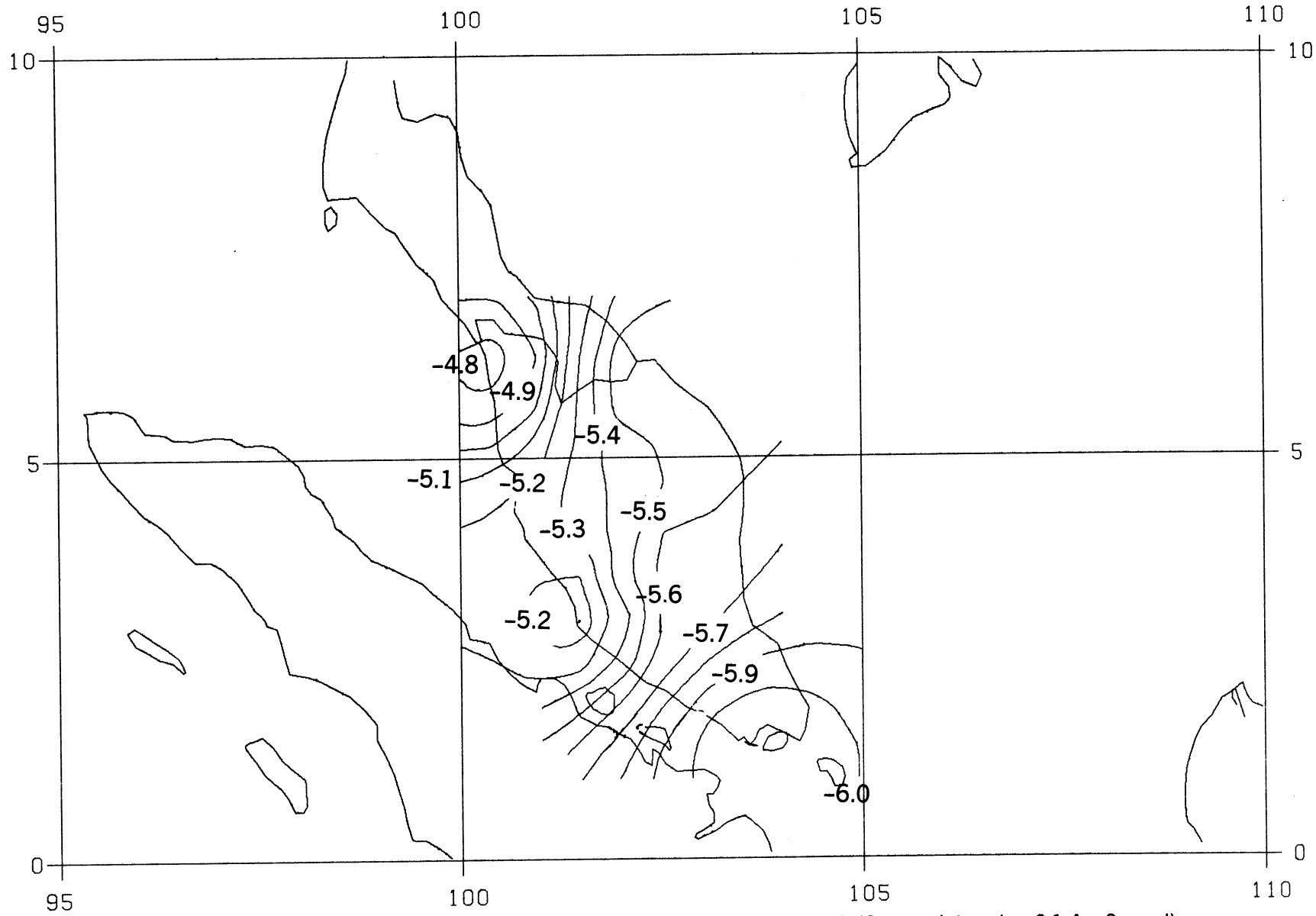

Figure 16.53. Contour Chart – Longitude Differences, WGS 84 Minus Kertau Datum 1948 (Contour Interval = 0.1 Arc Second)

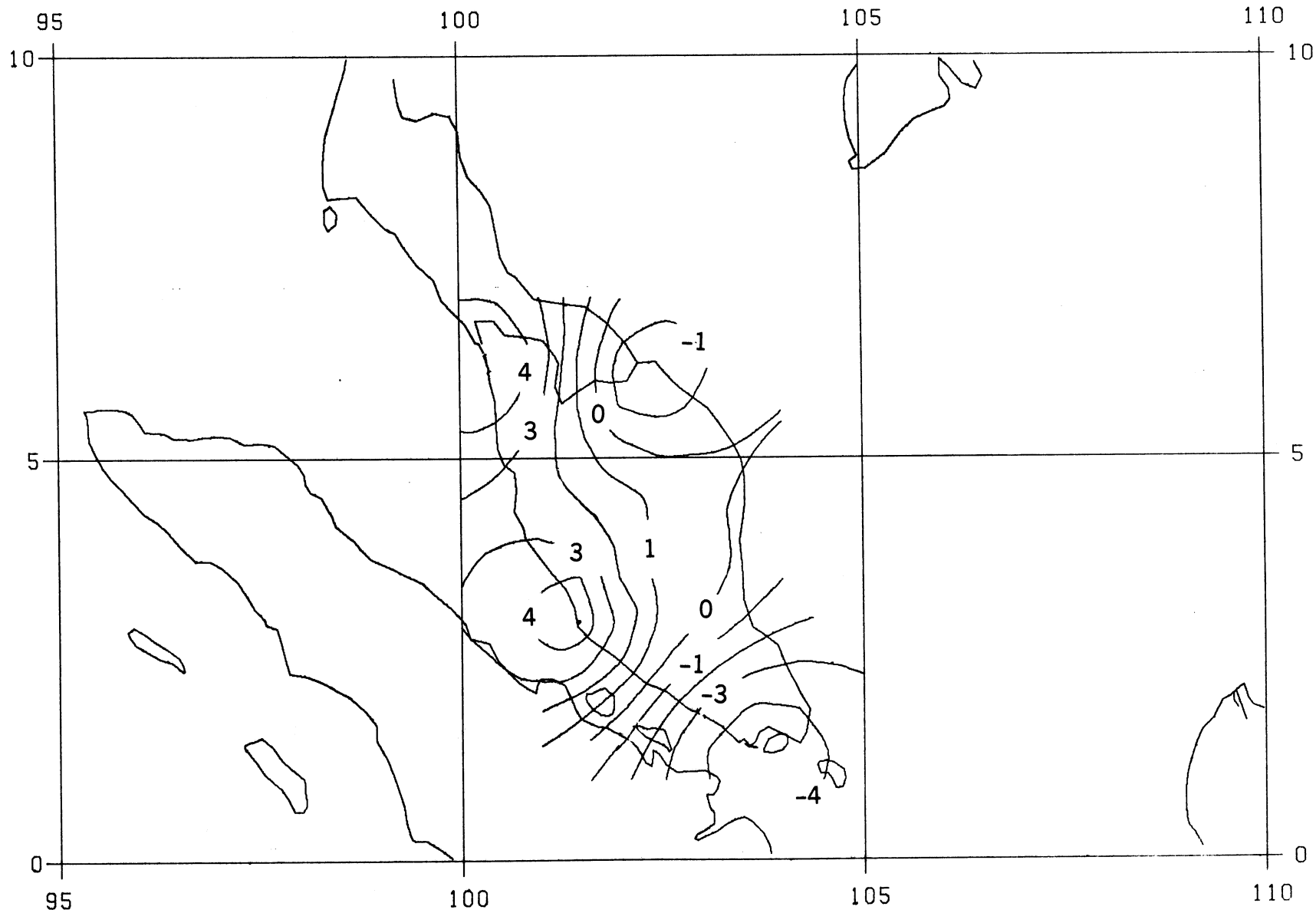

Figure 16.54. Contour Chart - Geodetic Height Differences, WGS 84 Minus Kertau Datum 1948 (Contour Interval = 1 Meter)

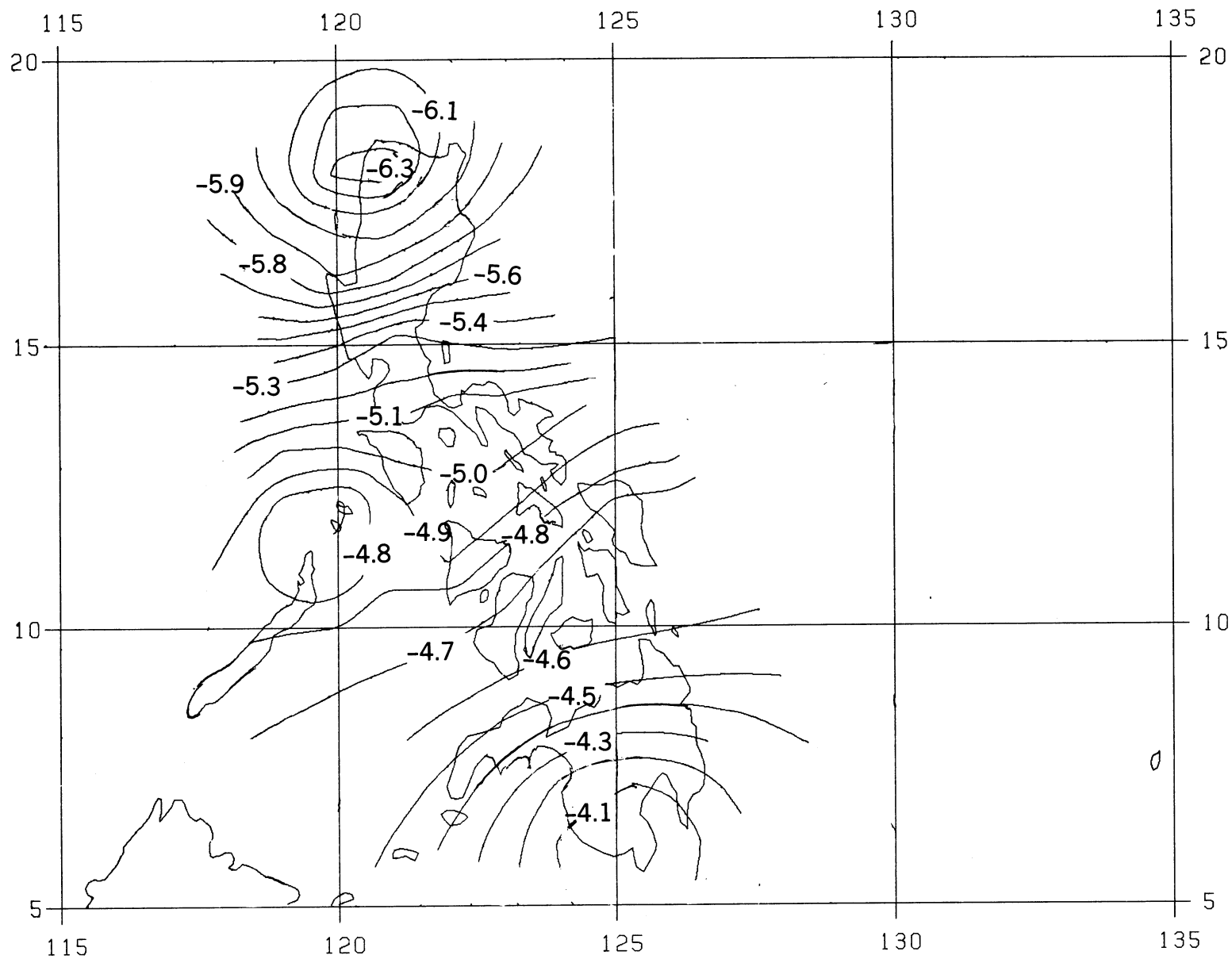

Figure 16.55. Contour Chart - Latitude Differences, WGS 84 Minus Luzon Datum (Contour Interval = 0.1 Arc Second)

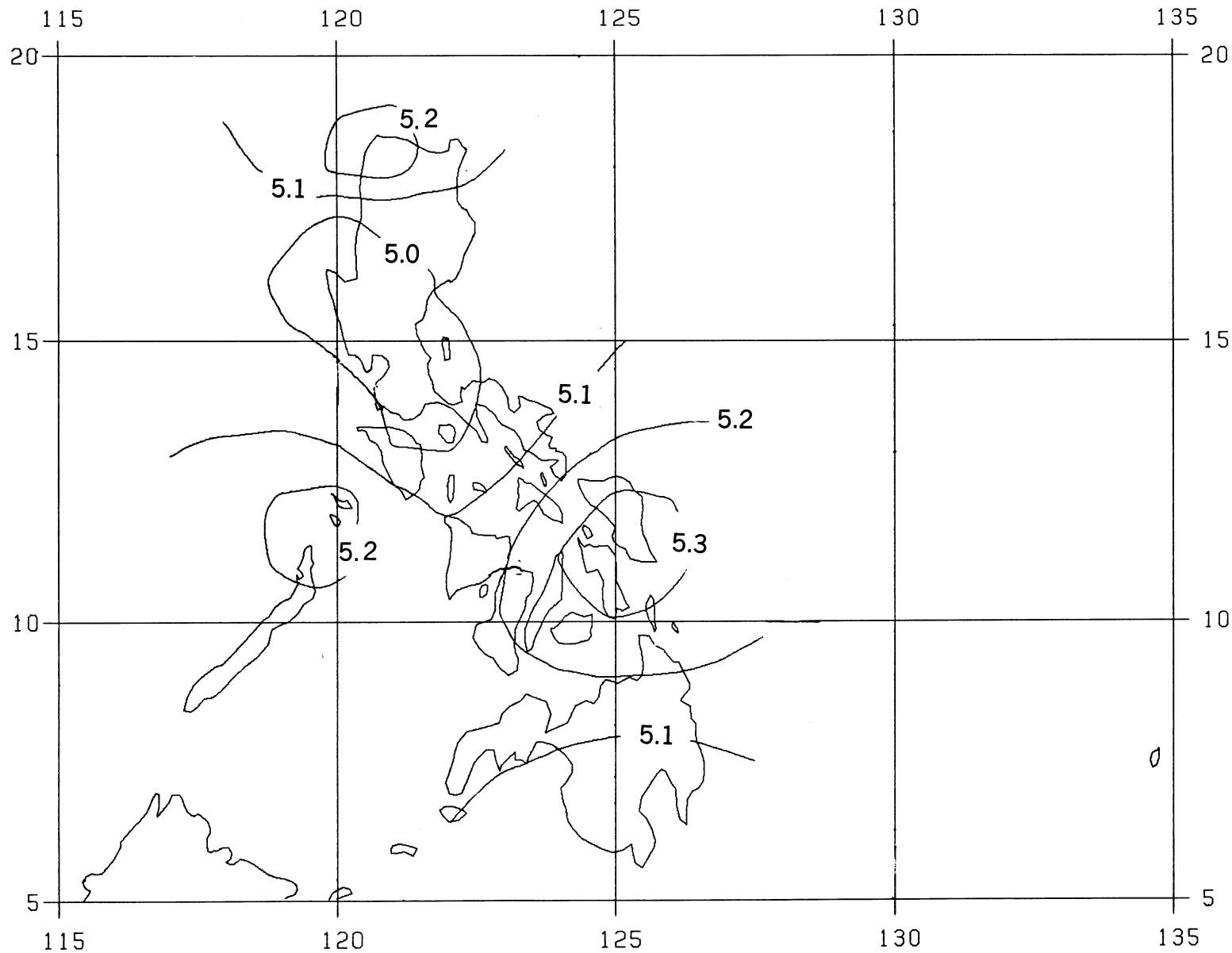

Figure 16.56. Contour Chart – Longitude Differences, WGS 84 Minus Luzon Datum (Contour Interval = 0.1 Arc Second)

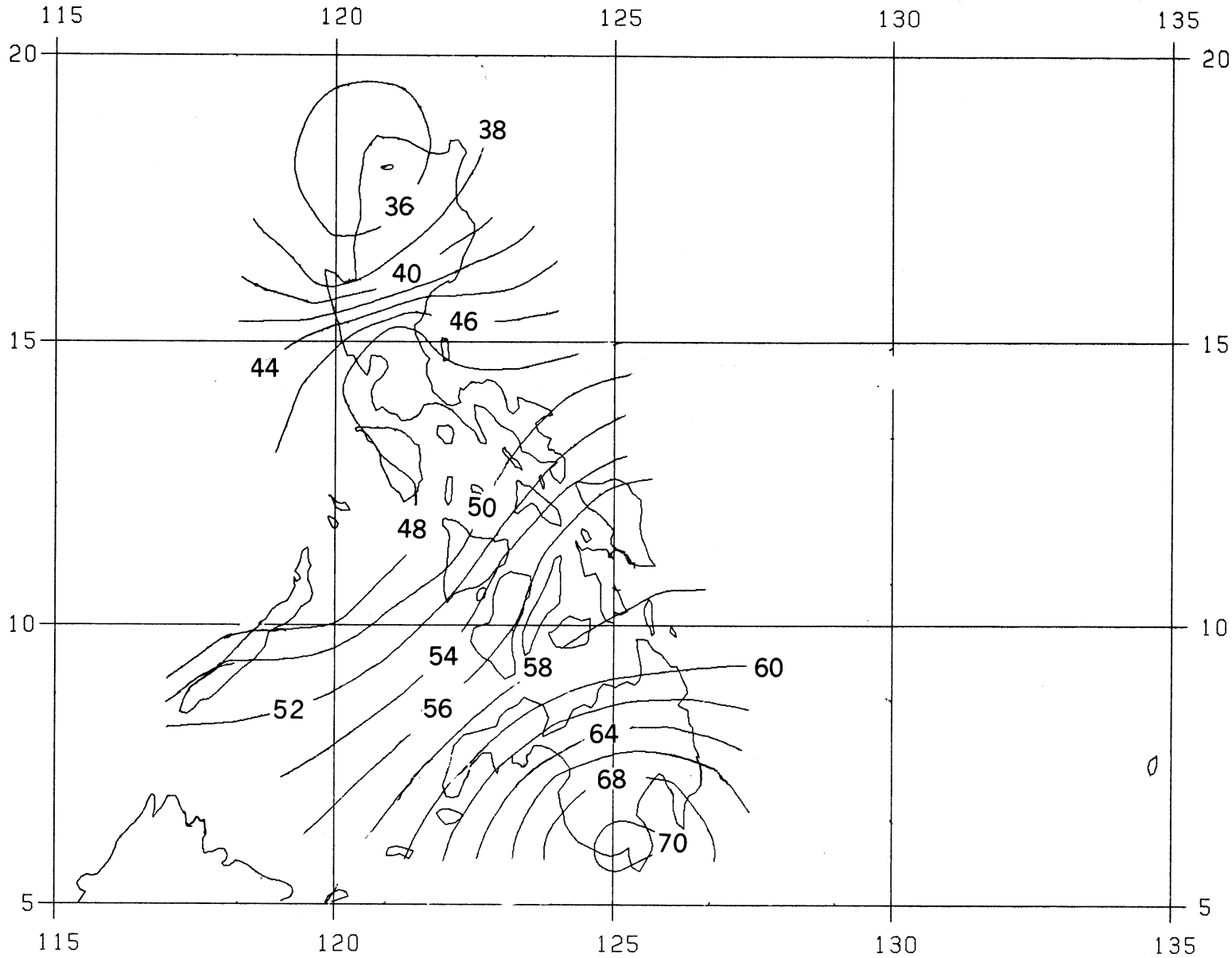

Figure 16.57. Contour Chart - Geodetic Height Differences, WGS 84 Minus Luzon Datum (Contour Interval = 2 Meters)

Figure 16.58. Contour Chart - Latitude Differences, WGS 84 Minus Merchich Datum
(Contour Interval = 0.1 Arc Second)

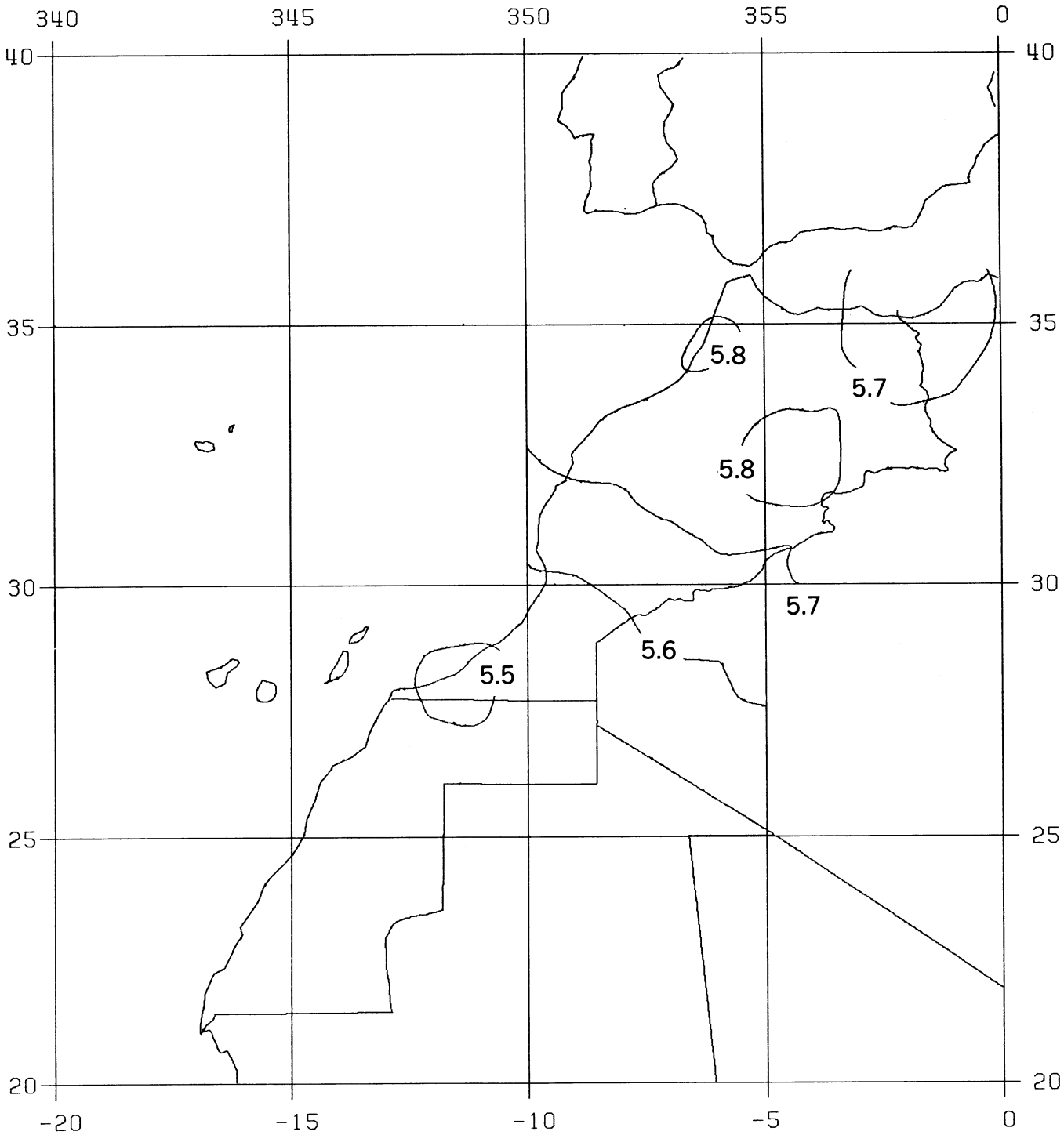

Figure 16.59. Contour Chart – Longitude Differences, WGS 84 Minus Merchich Datum
(Contour Interval = 0.1 Arc Second)

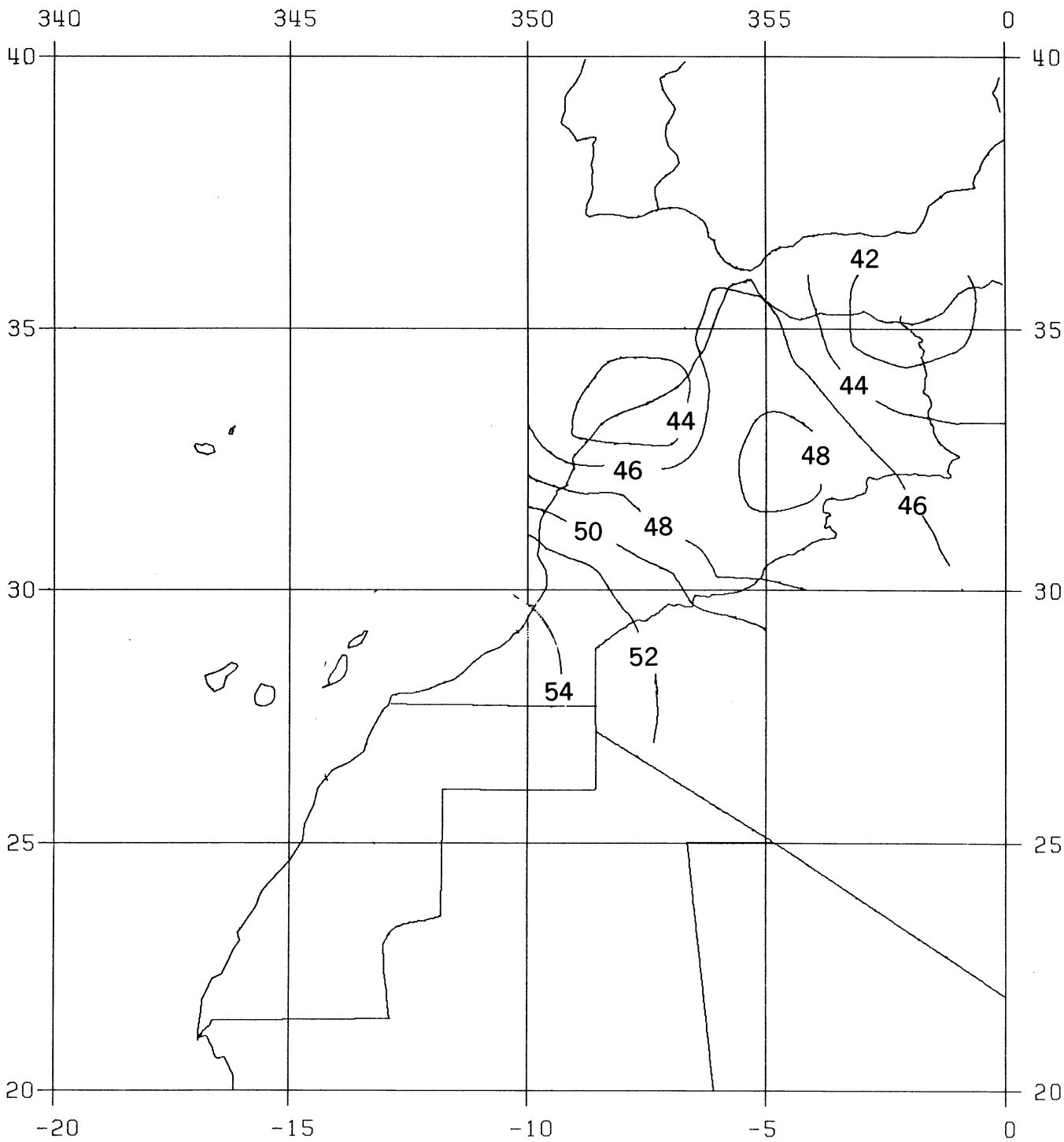

Figure 16.60. Contour Chart–Geodetic Height Differences, WGS 84 Minus Merchich Datum (Contour Interval = 2 Meters)

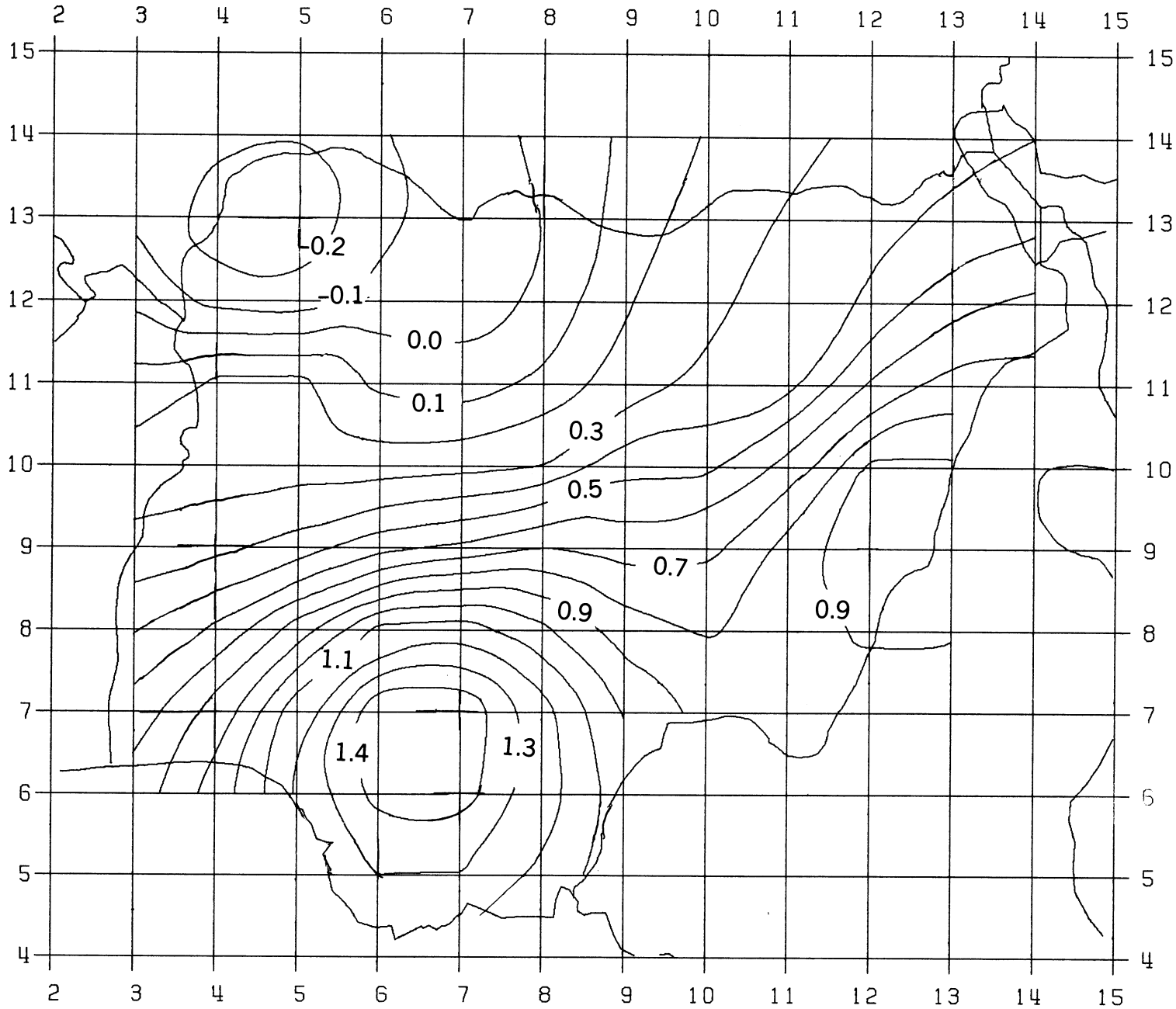

Figure 16.61. Contour Chart–Latitude Differences, WGS 84 Minus Minna Datum (Contour Interval = 0.1 Arc Second)

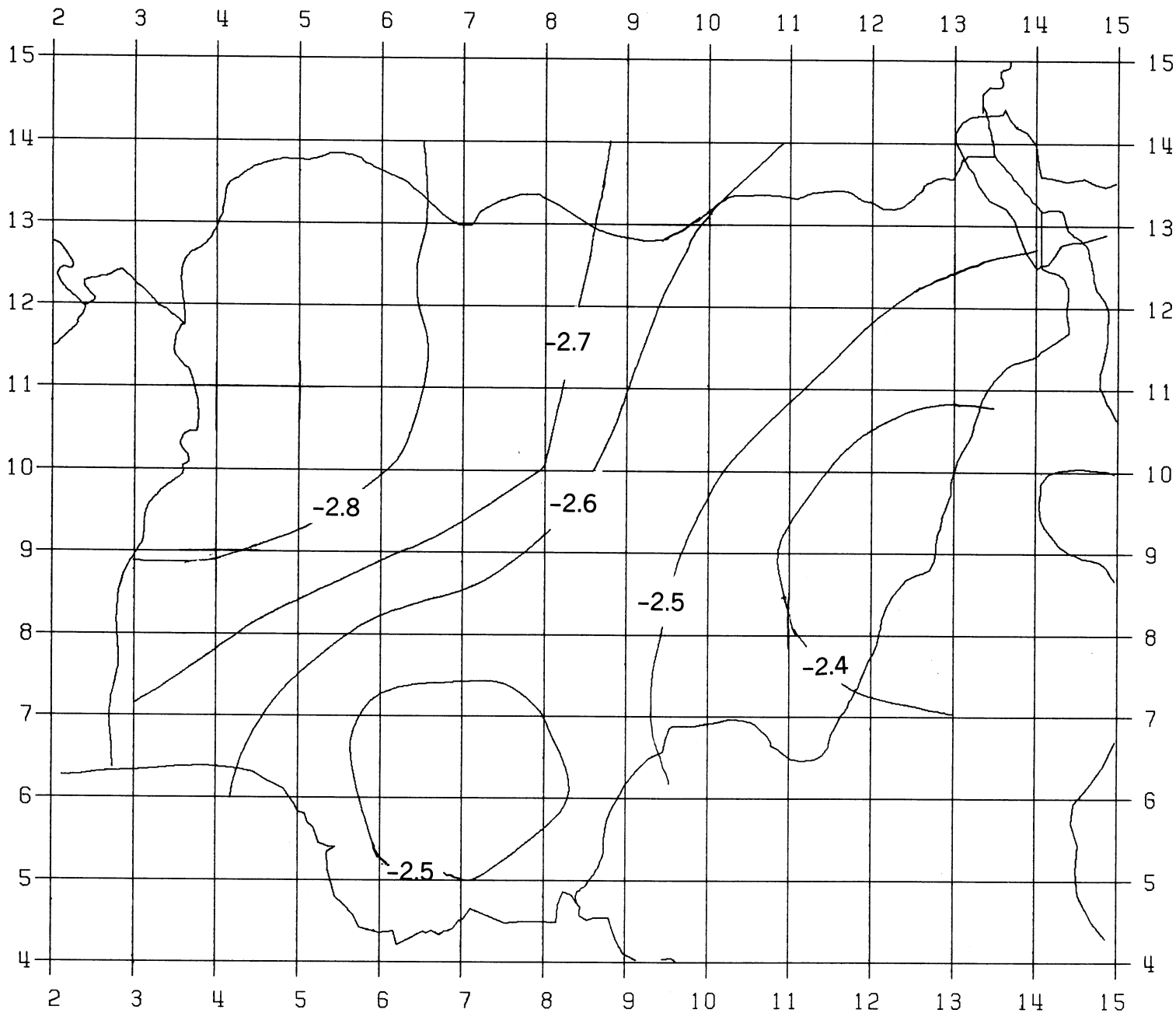

Figure 16.62. Contour Chart - Longitude Differences, WGS 84 Minus Minna Datum (Contour Interval = 0.1 Arc Second)

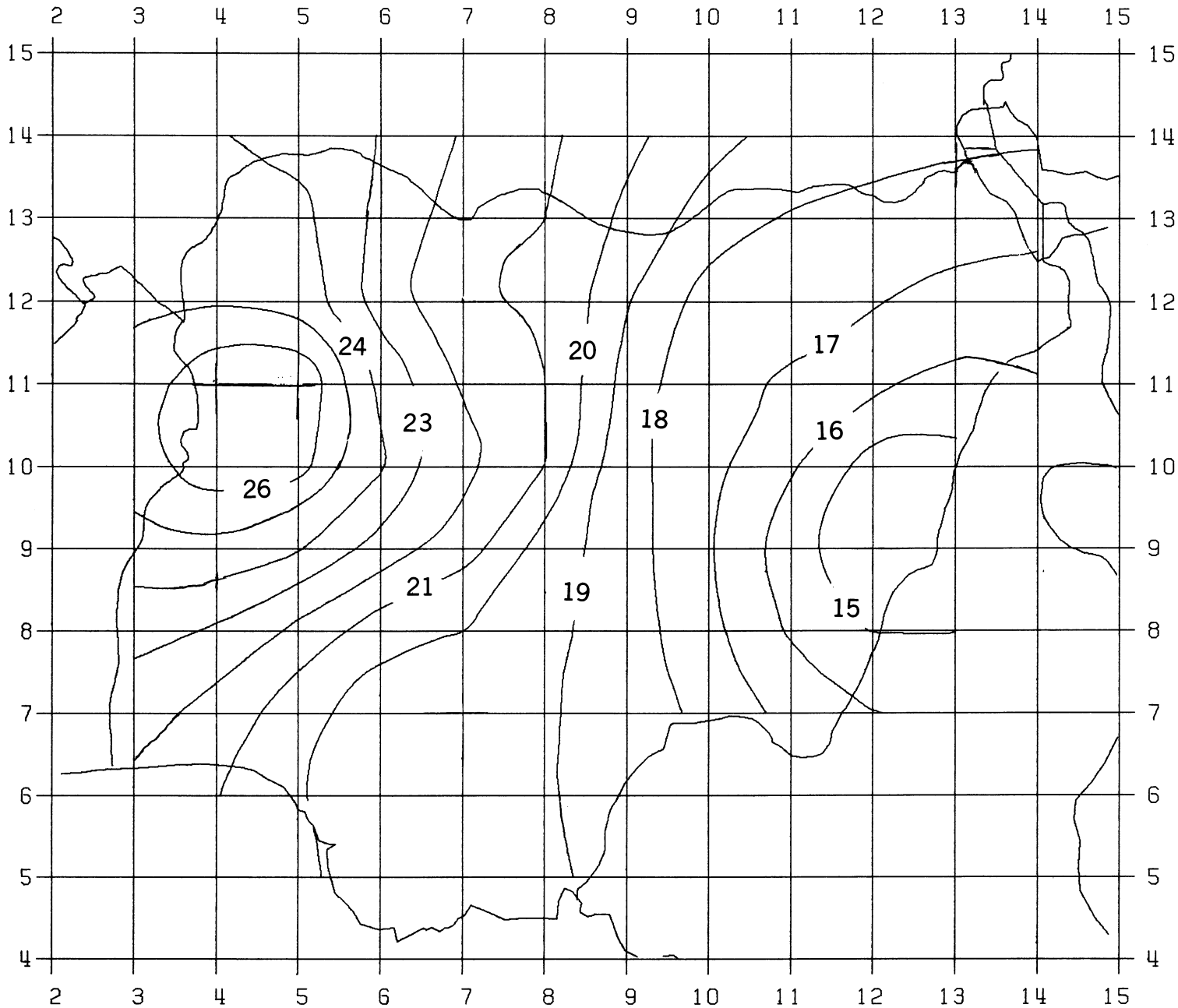

Figure 16.63. Contour Chart–Geodetic Height Differences, WGS 84 Minus Minna Datum (Contour Interval = 1 Meter)

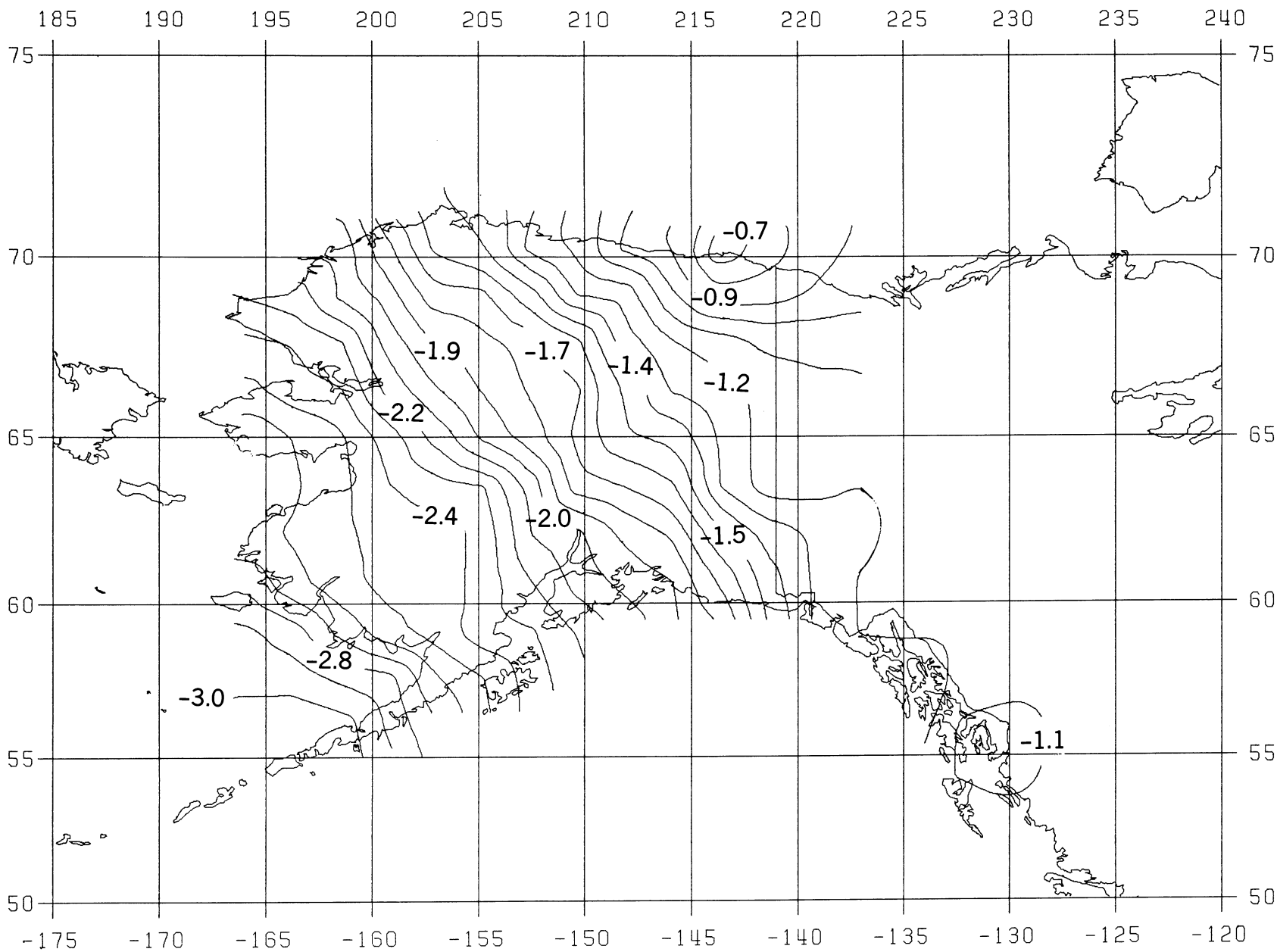

Figure 16.64. Contour Chart - Latitude Differences, WGS 84 Minus NAD 27 (Alaska) (Contour Interval = 0.1 Arc Second)

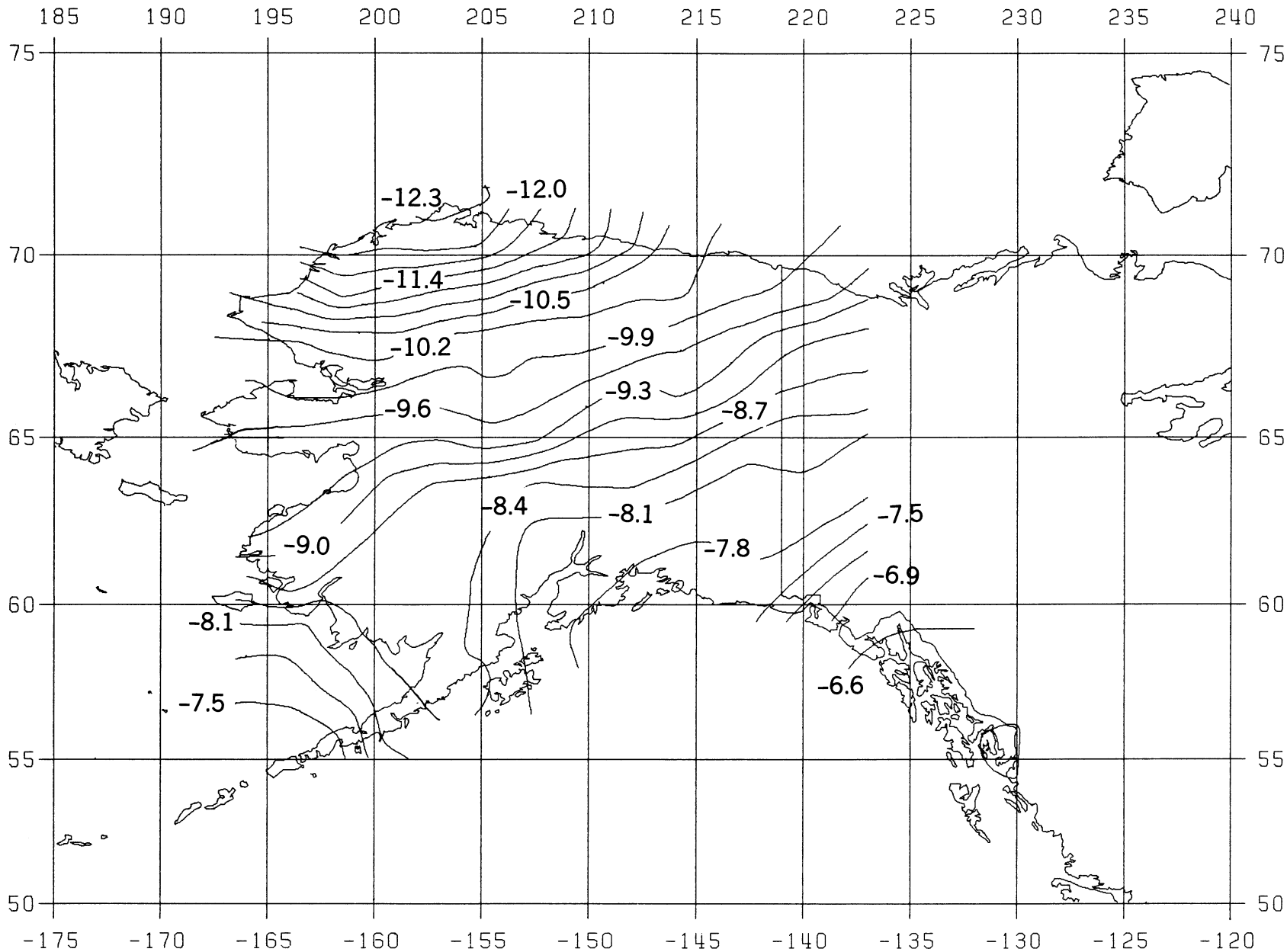

Figure 16.65. Contour Chart - Longitude Differences, WGS 84 Minus NAD 27 (Alaska) (Contour Interval = 0.3 Arc Second)

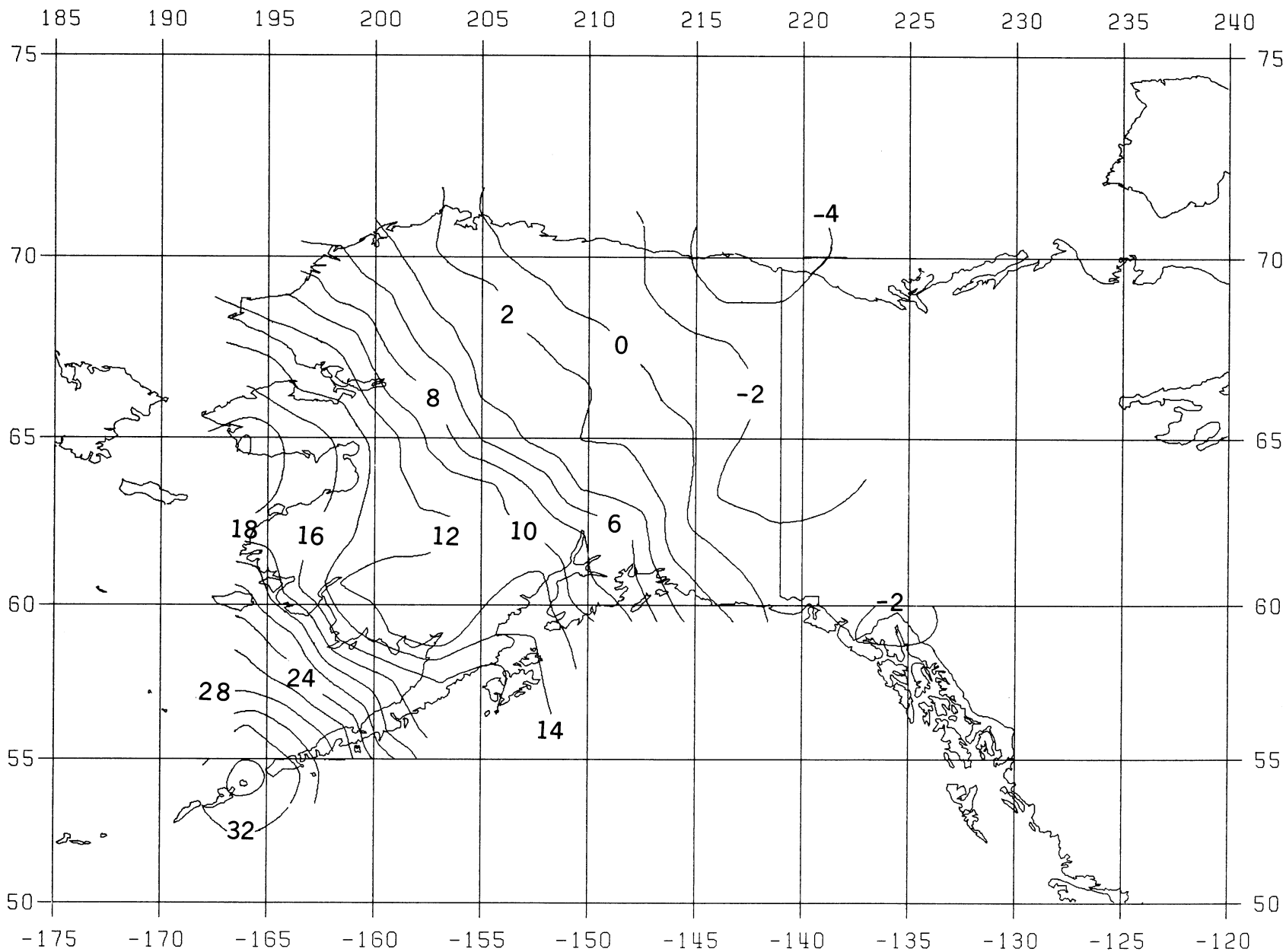

Figure 16.66. Contour Chart–Geodetic Height Differences, WGS 84 Minus NAD 27 (Alaska) (Contour Interval = 2 Meters)

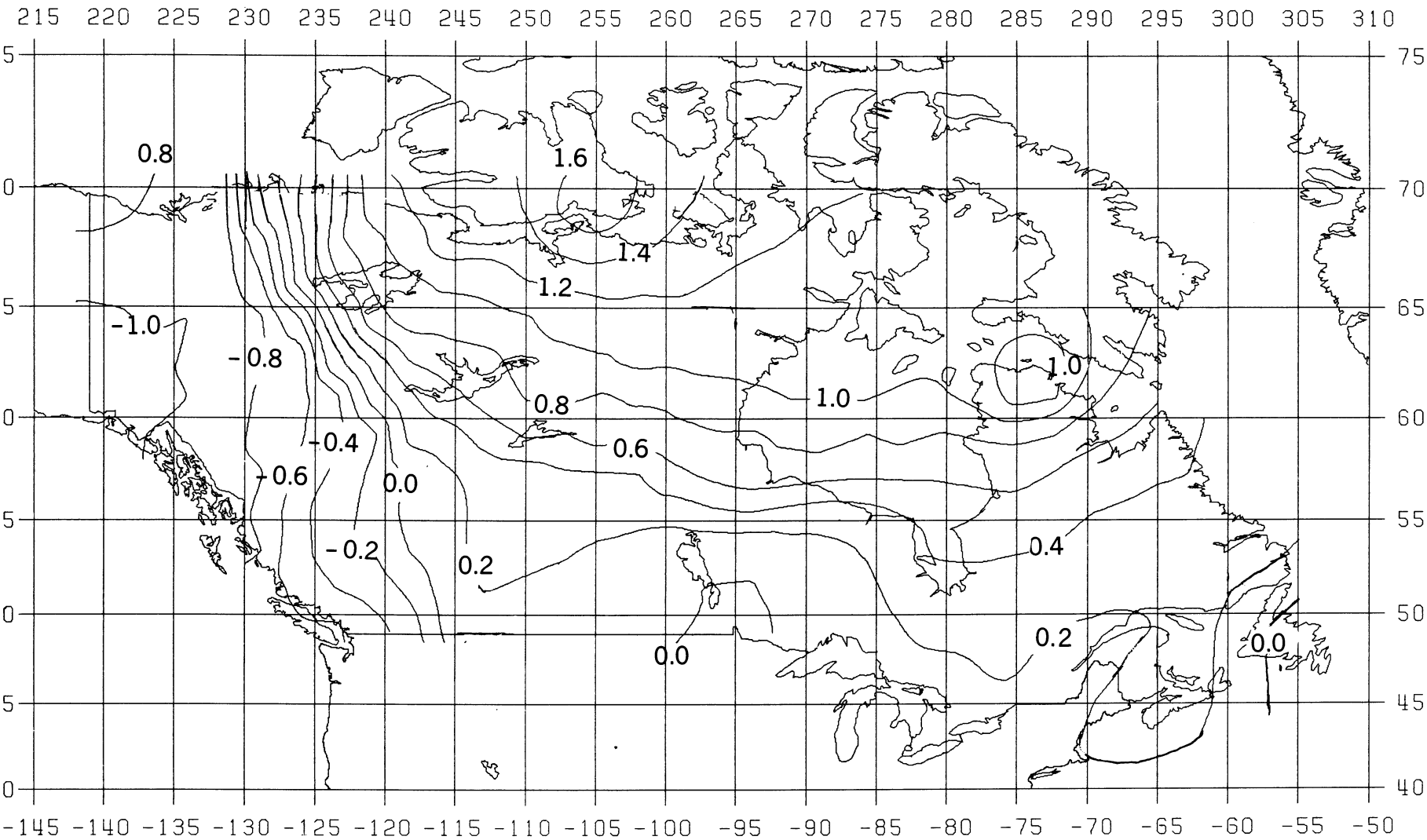

Figure 16.67. Contour Chart - Latitude Differences, WGS 84 Minus NAD 27 (Canada) (Contour Interval = 0.2 Arc Second)

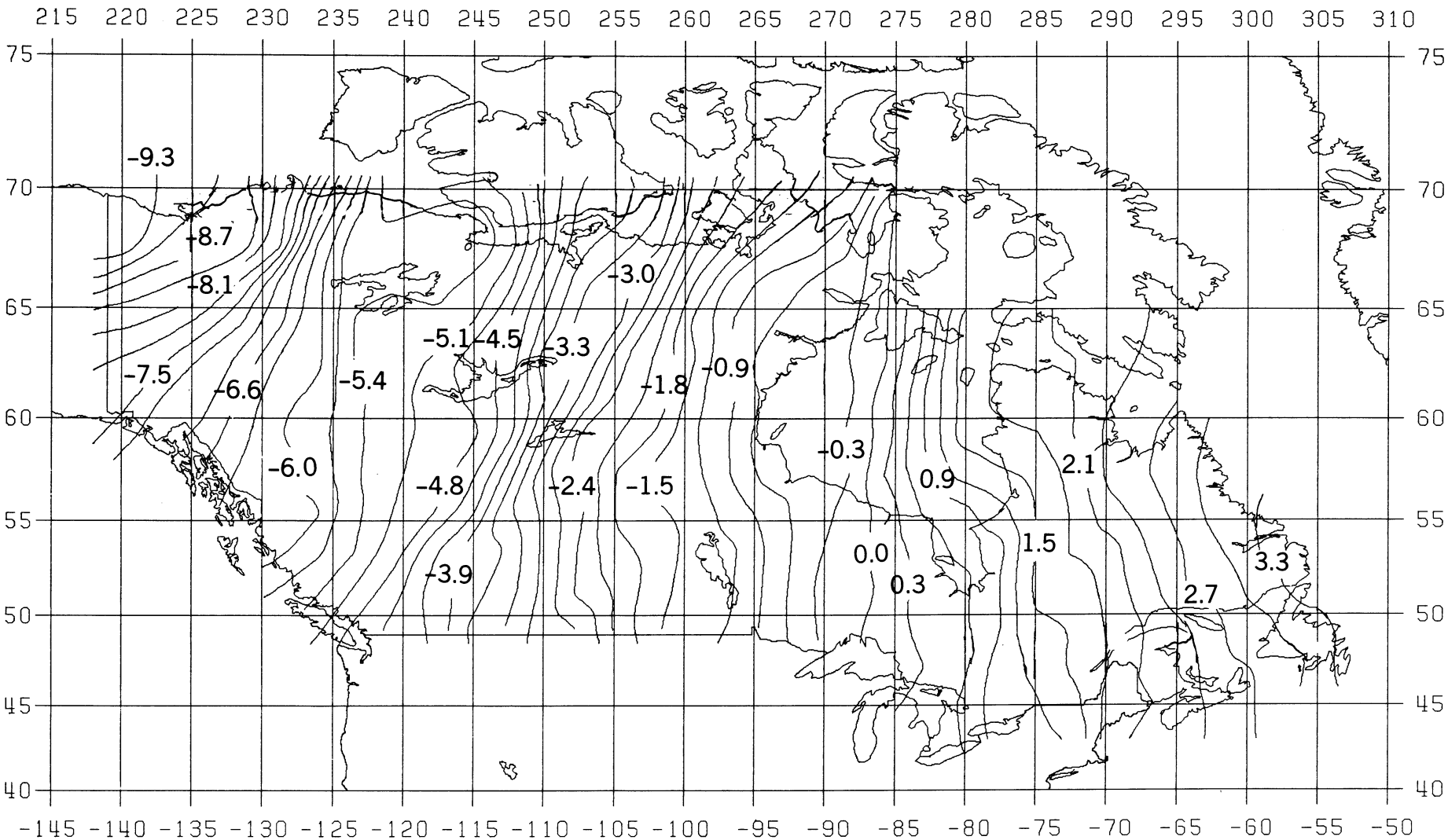

Figure 16.68. Contour Chart - Longitude Differences, WGS 84 Minus NAD 27 (Canada) (Contour Interval = 0.3 Arc Second)

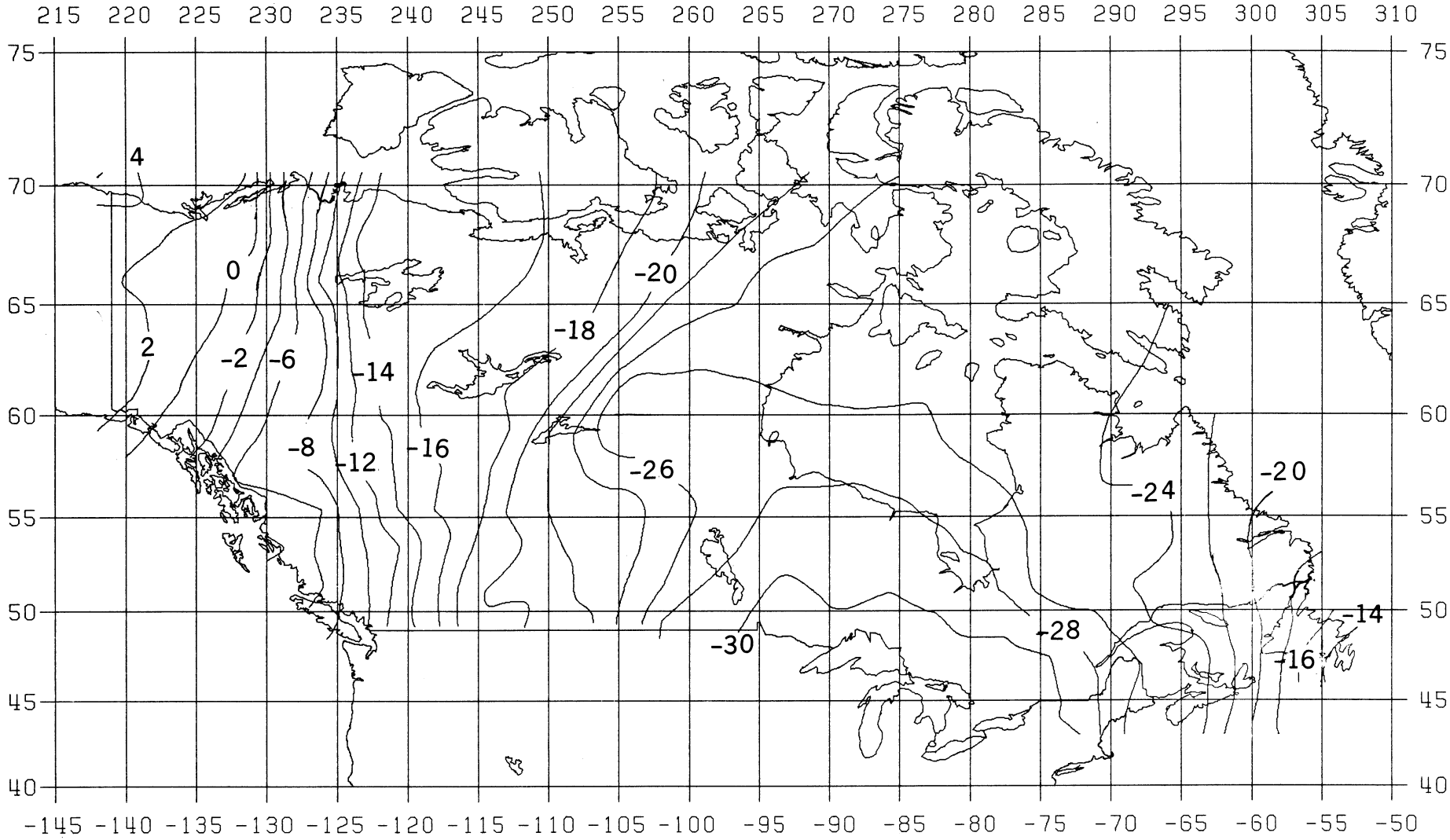

Figure 16.69. Contour Chart–Geodetic Height Differences, WGS 84 Minus NAD 27 (Canada) (Contour Interval = 2 Meters)

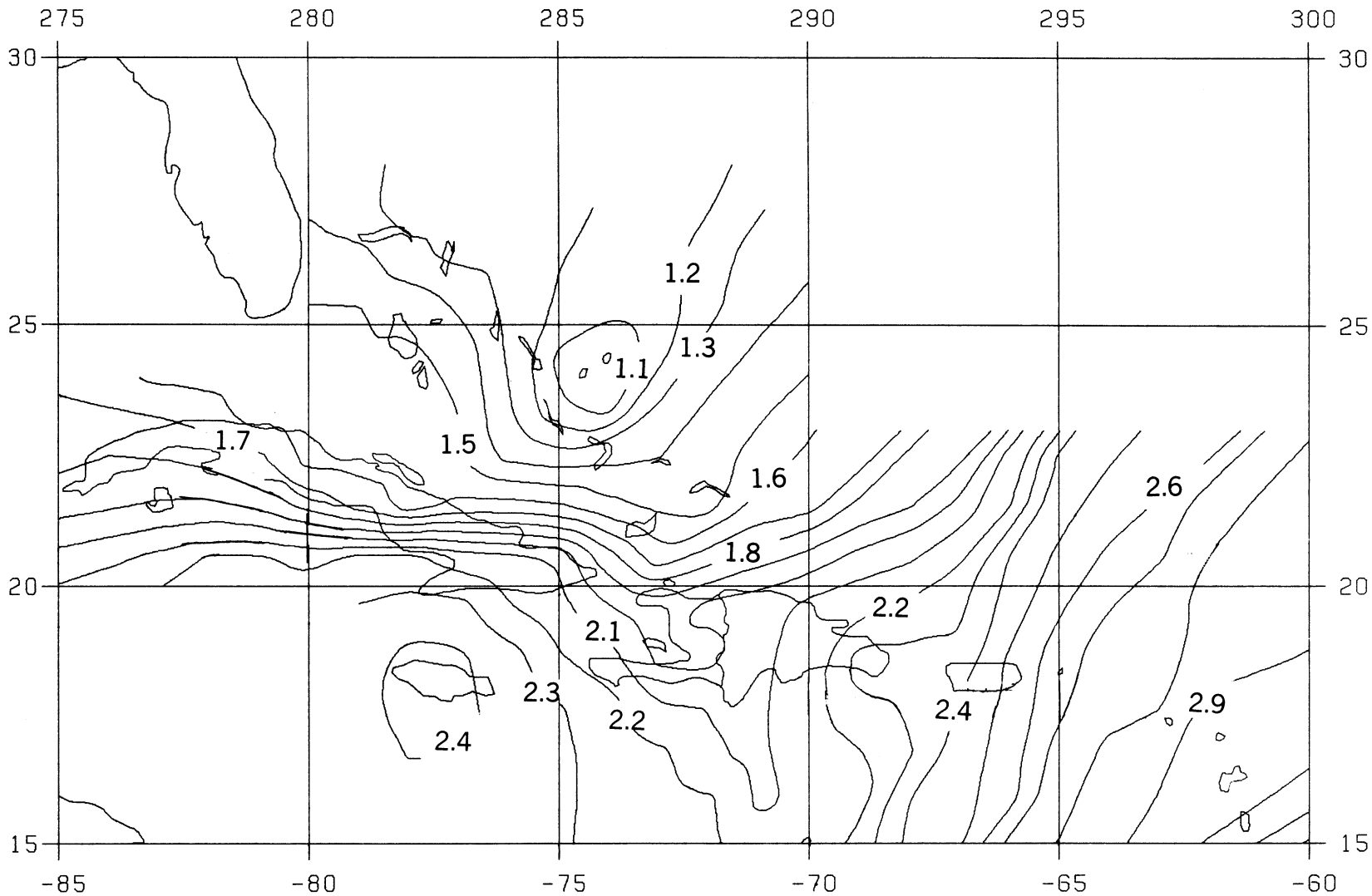

Figure 16.70. Contour Chart–Latitude Differences, WGS 84 Minus NAD 27 (Caribbean) (Contour Interval = 0.1 Arc Second

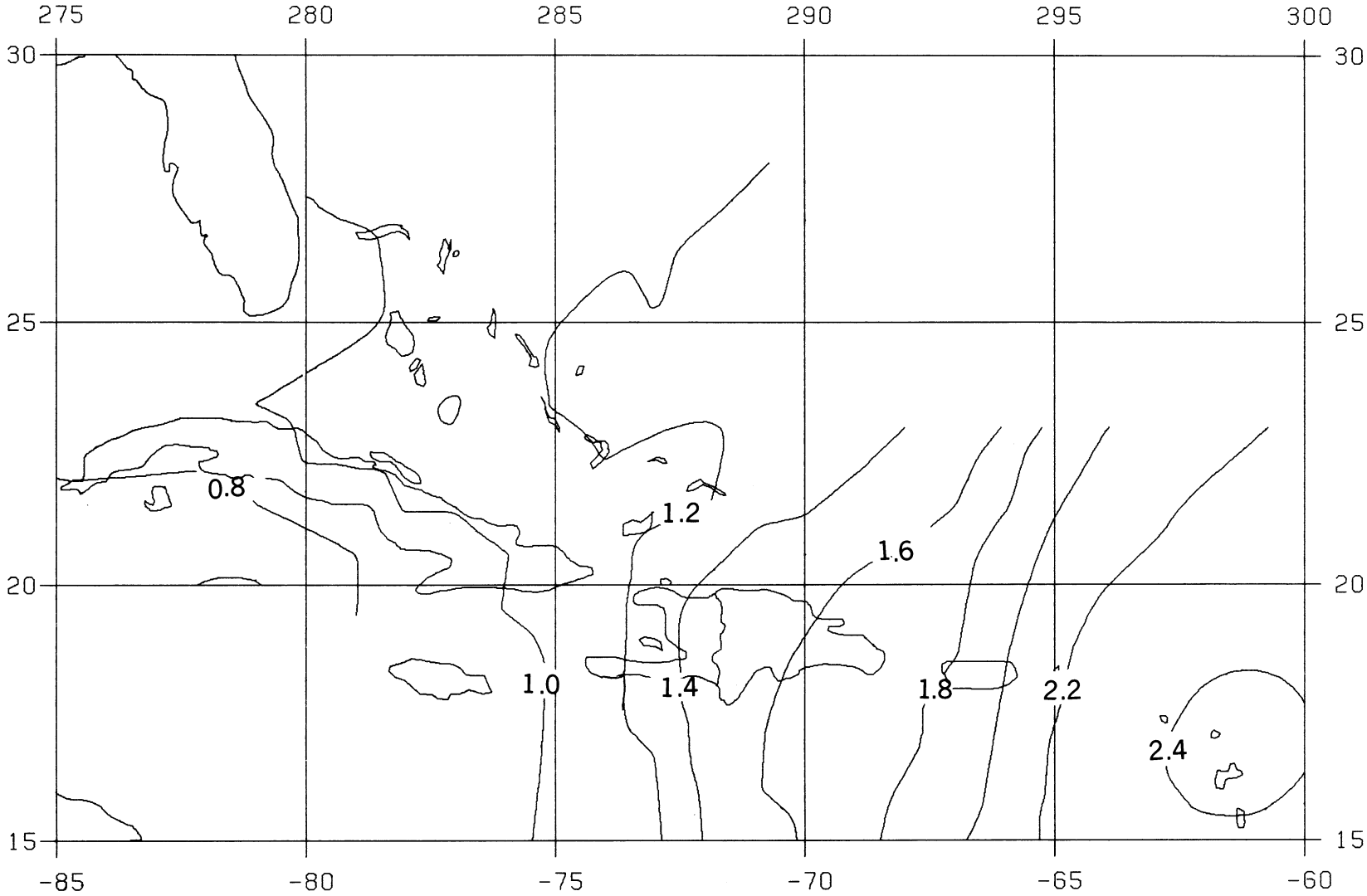

Figure 16.71. Contour Chart–Longitude Differences, WGS 84 Minus NAD 27 (Caribbean) (Contour Interval = 0.2 Arc Second)

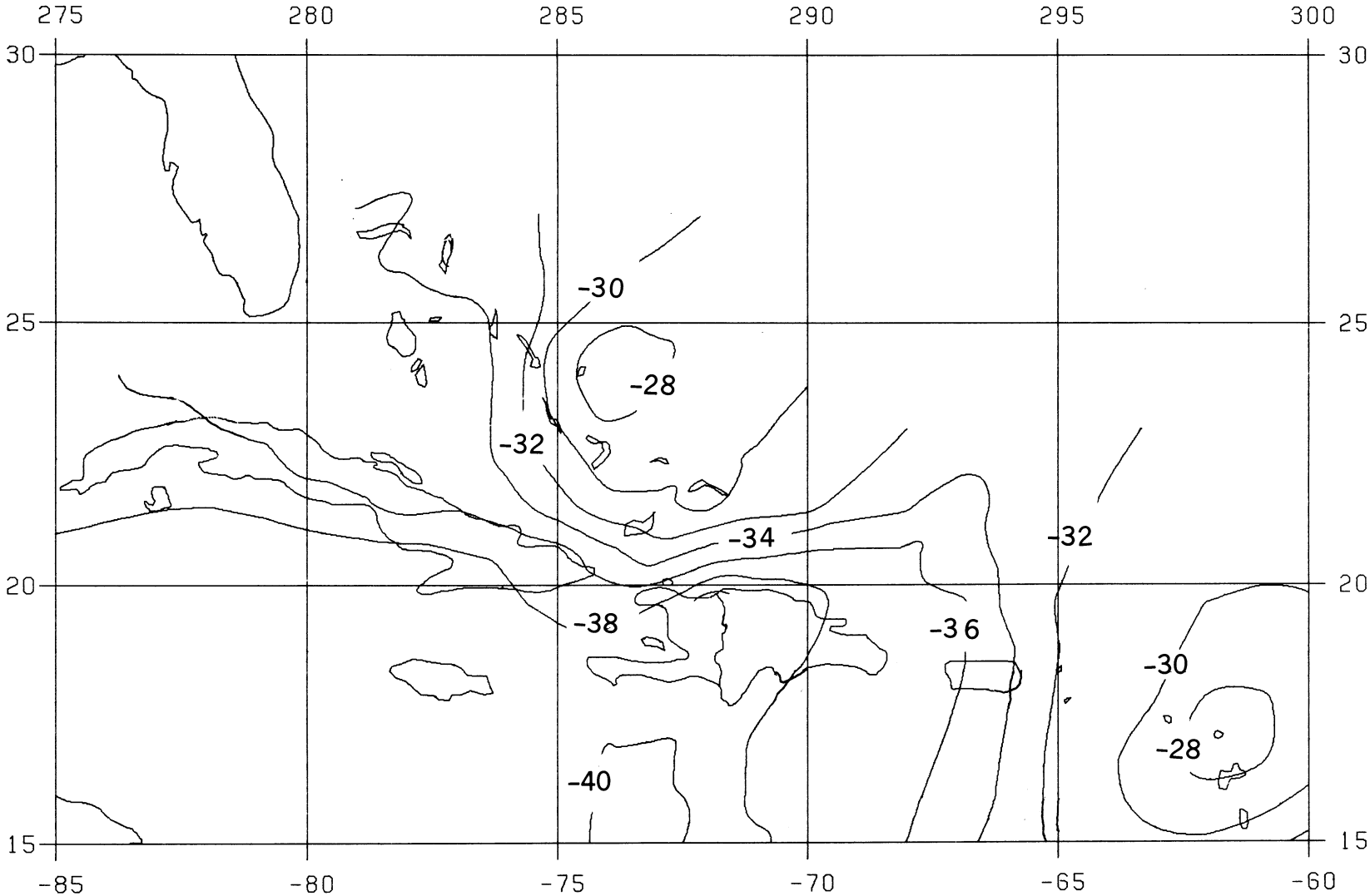

Figure 16.72. Contour Chart-Geodetic Height Differences, WGS 84 Minus NAD 27 (Caribbean) (Contour Interval = 2 Meters)

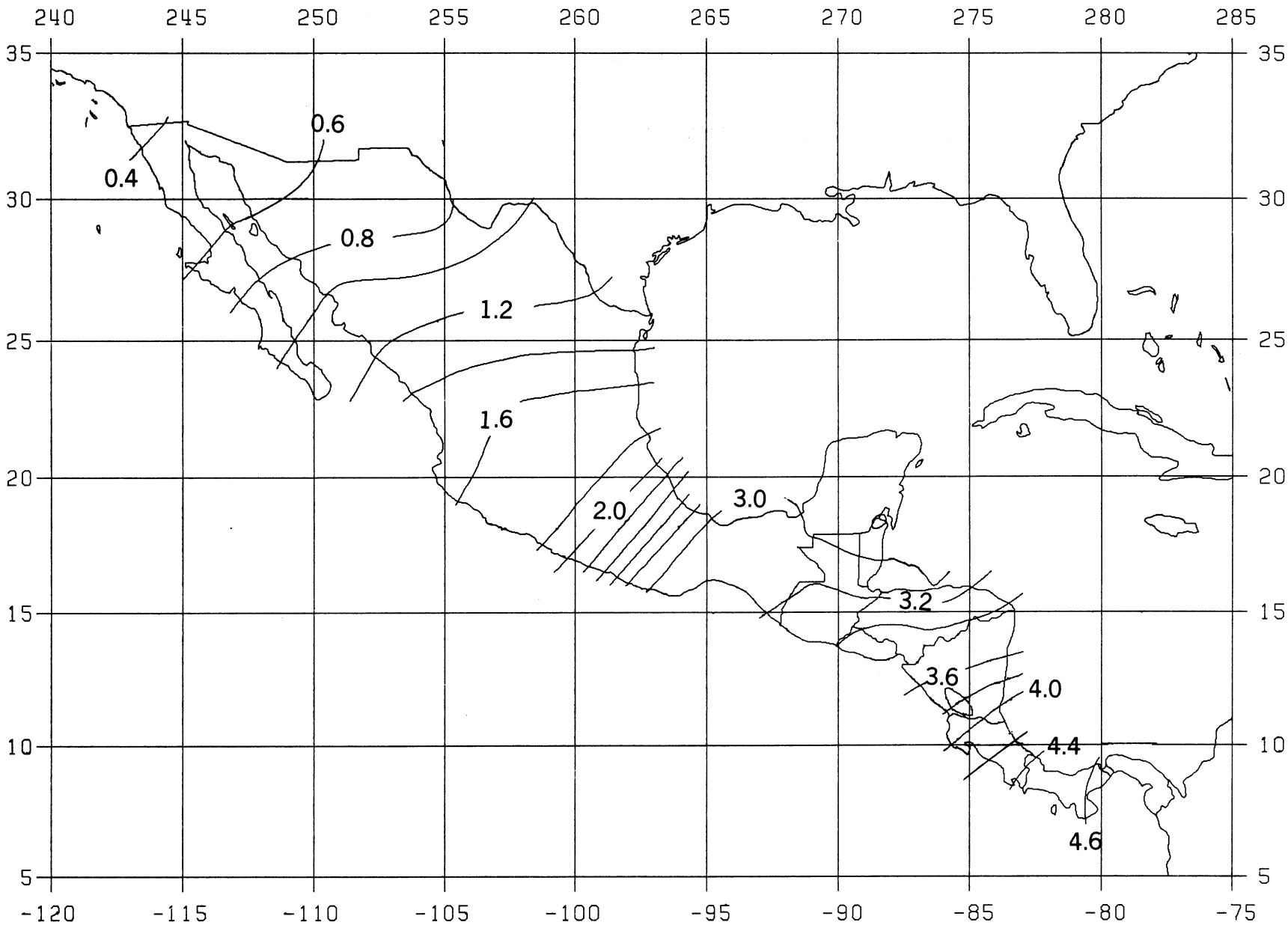

Figure 16.73. Contour Chart–Latitude Differences, WGS 84 Minus NAD 27 (Mexico, Central America) (Contour Interval = 0.2 Arc Second)

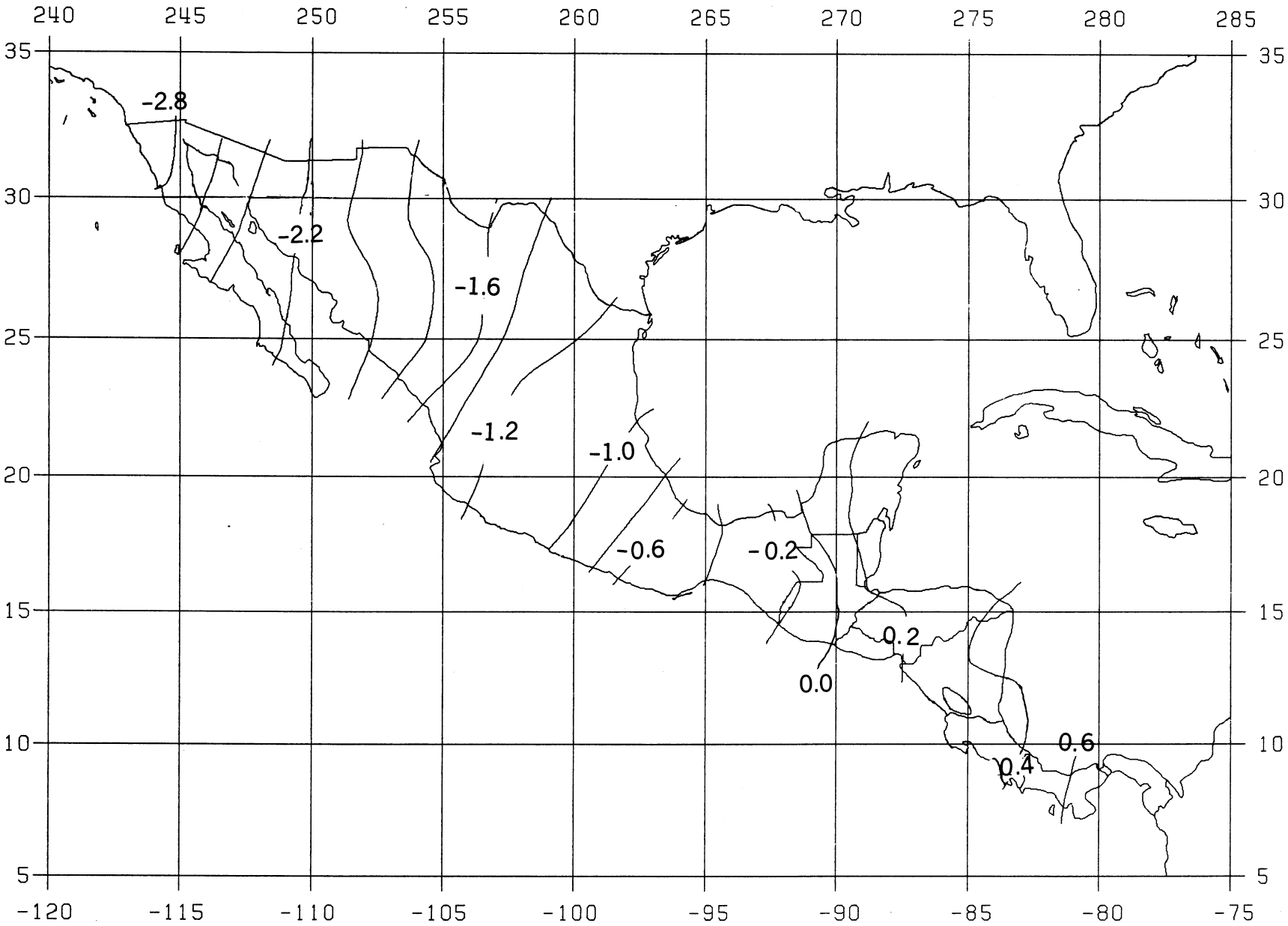

Figure 16.74. Contour Chart-Longitude Differences, WGS 84 Minus NAD 27 (Mexico, Central America) (Contour Interval = 0.2 Arc Second)

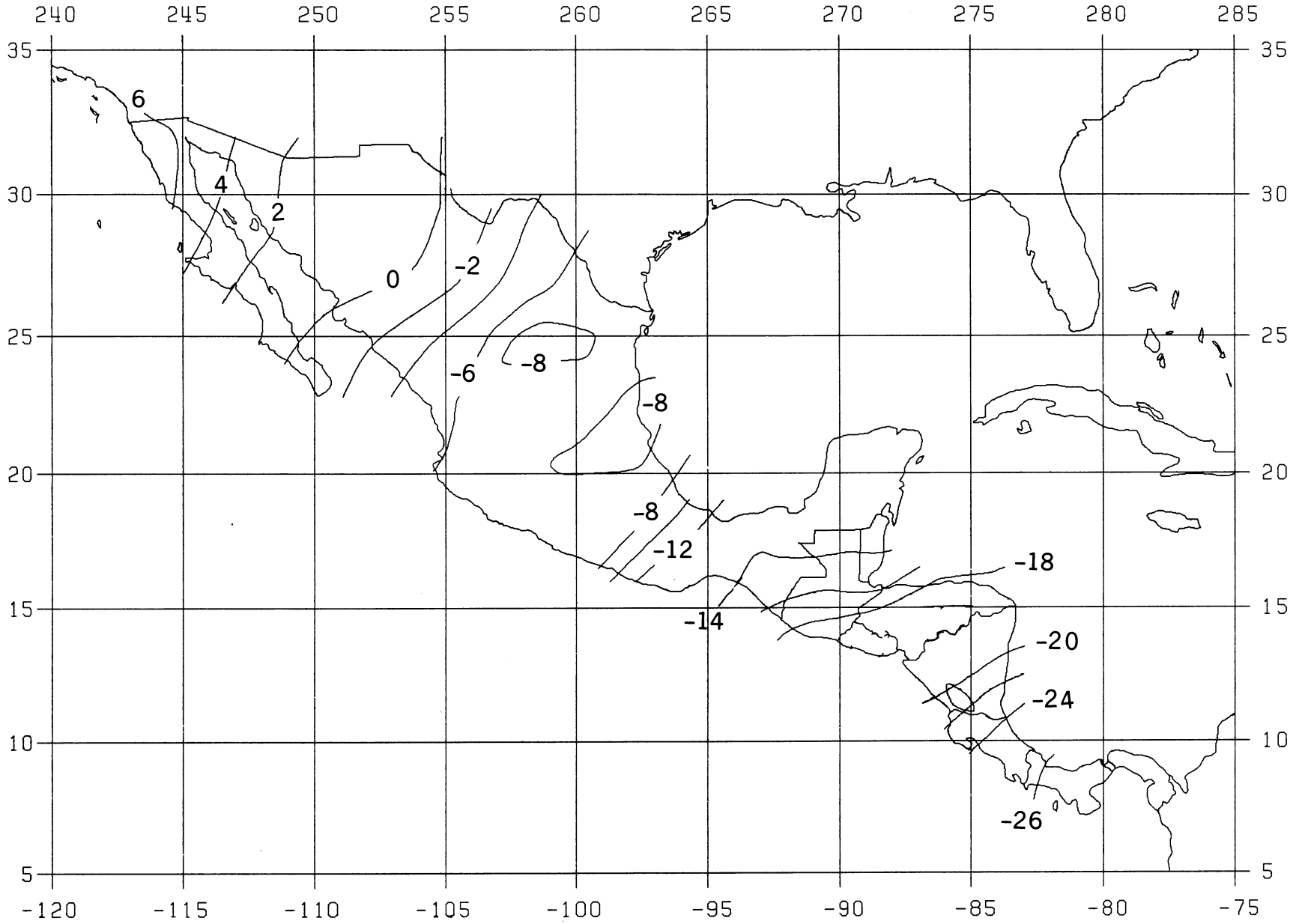

Figure 16.75. Contour Chart-Geodetic Height Differences, WGS 84 Minus NAD 27 (Mexico, Central America) (Contour Interval = 2 Meters)

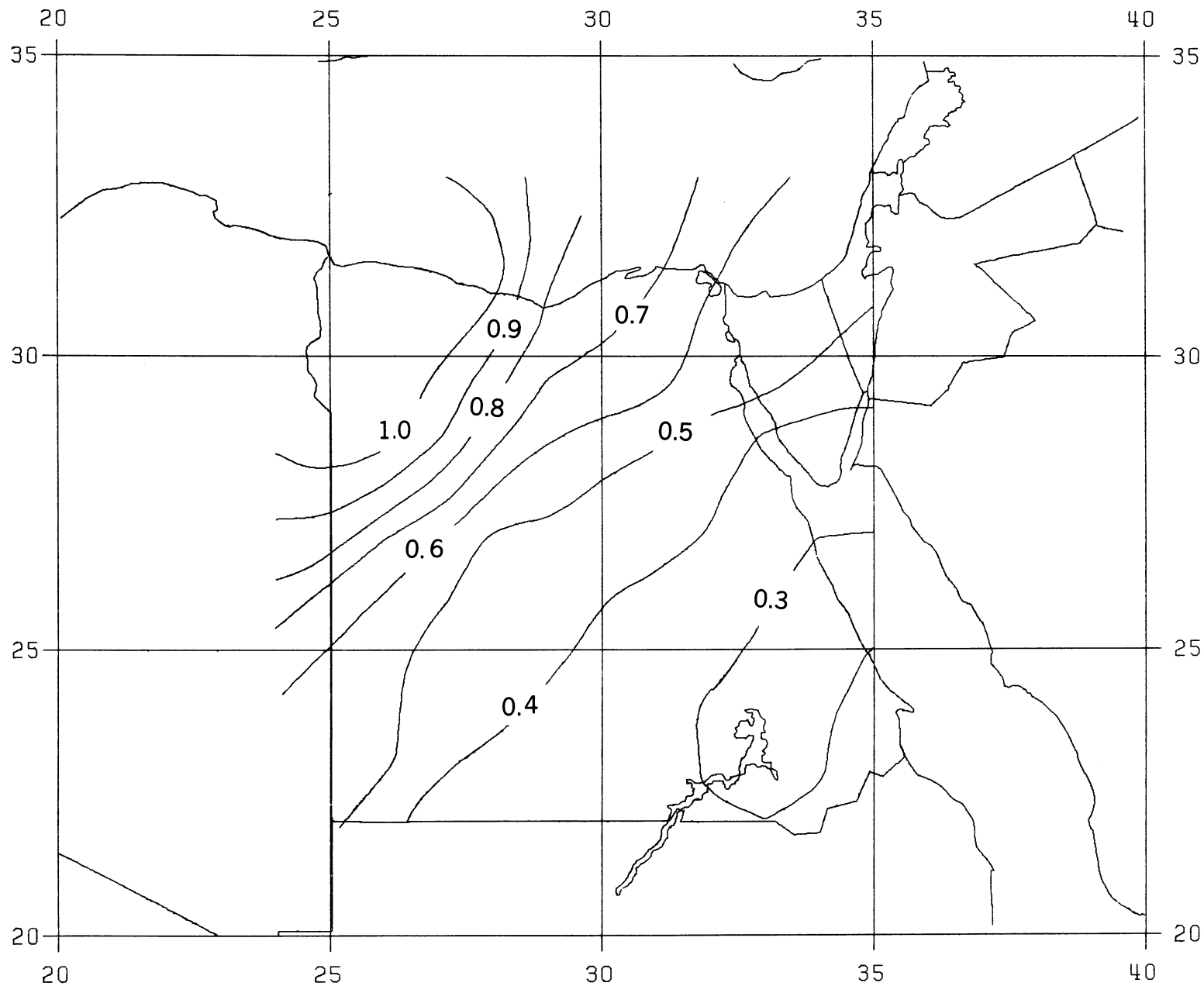

Figure 16.76. Contour Chart - Latitude Differences, WGS 84 Minus Old Egyptian Datum (Contour Interval = 0.1 Arc Second)

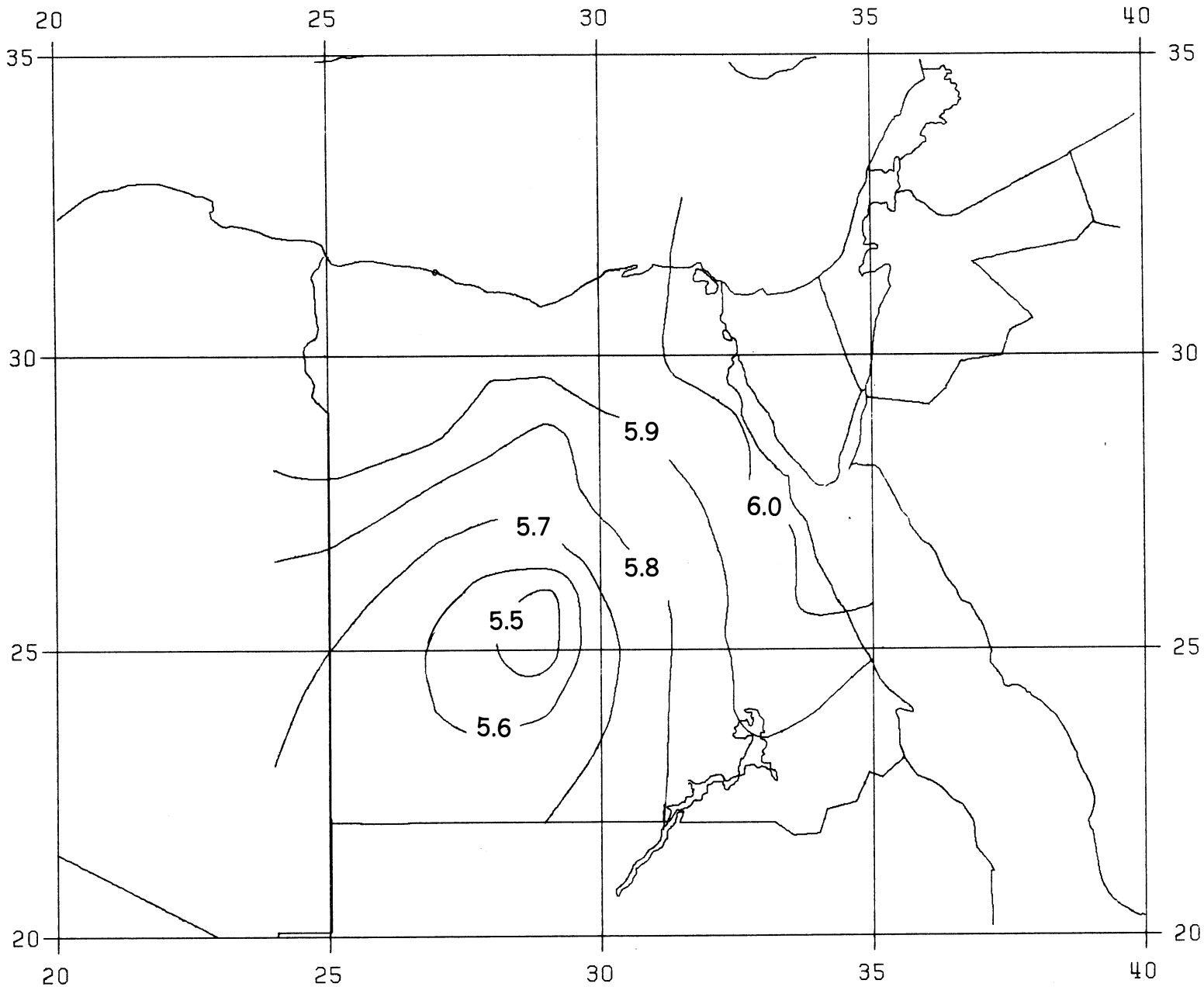

Figure 16.77. Contour Chart–Longitude Differences, WGS 84 Minus Old Egyptian Datum (Contour Interval = 0.1 Arc Second)

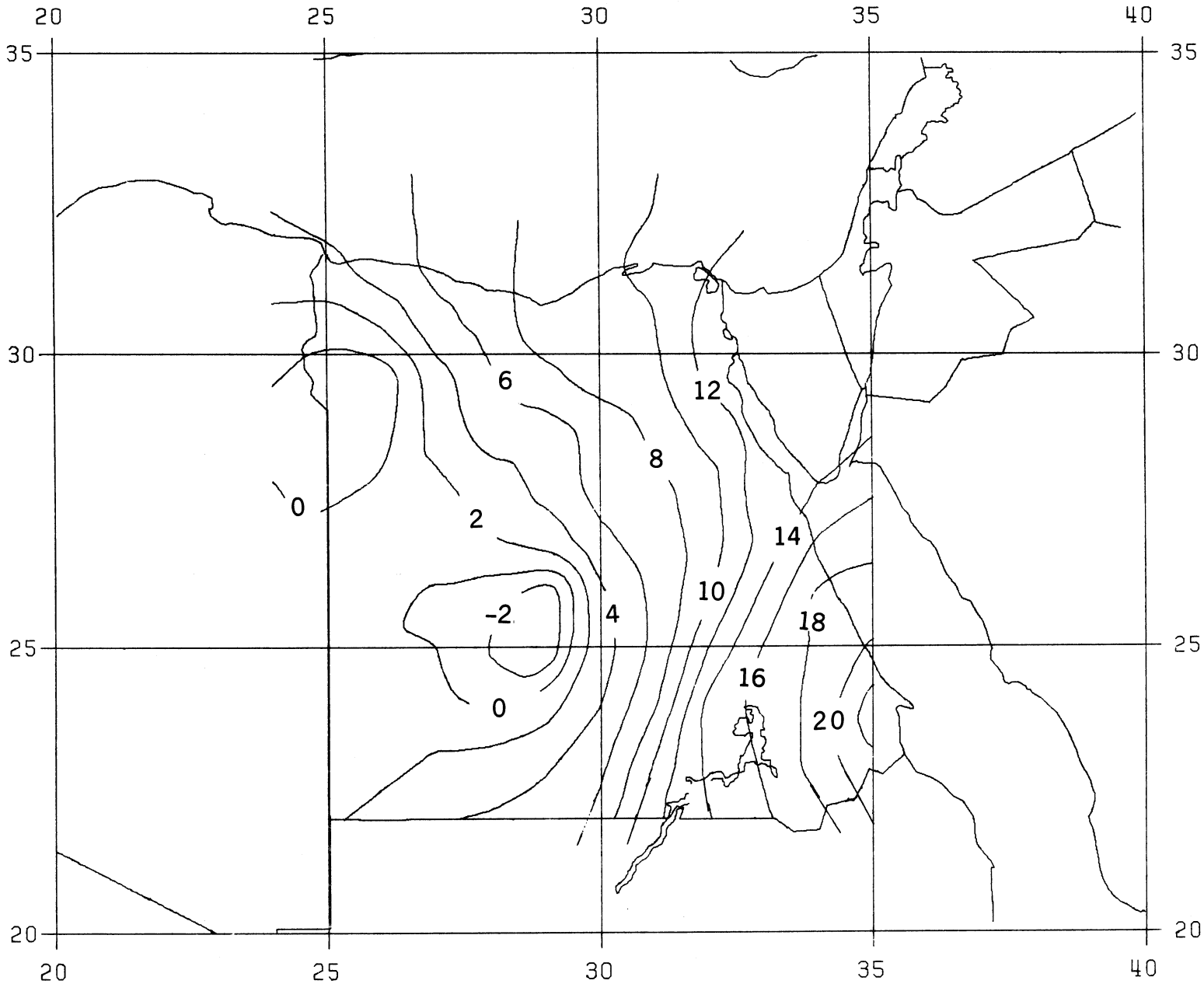

Figure 16.78. Contour Chart–Geodetic Height Differences, WGS 84 Minus Old Egyptian Datum (Contour Interval = 2 Meters)

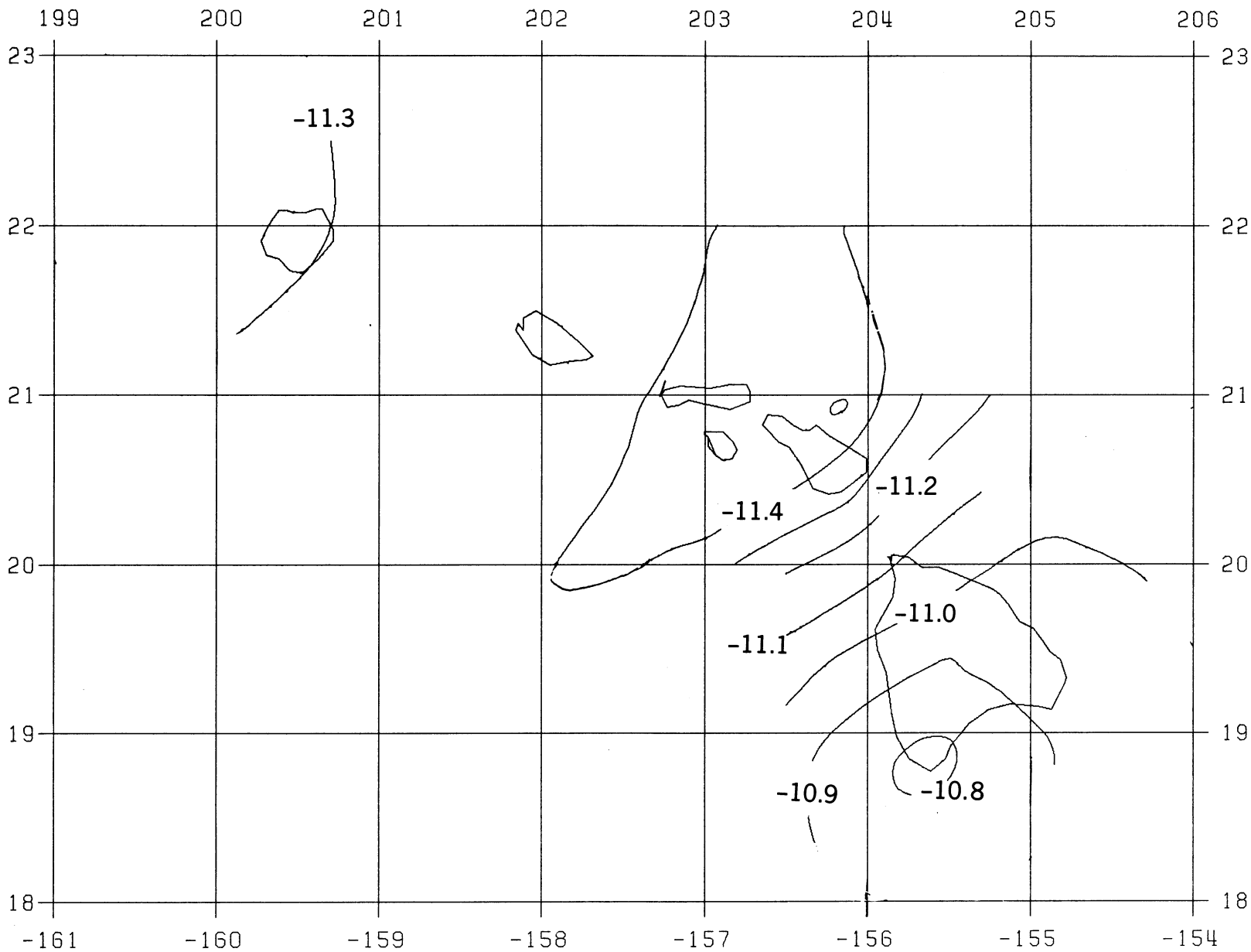

Figure 16.79. Contour Chart-Latitude Differences, WGS 84 Minus Old Hawaiian Datum (Contour Interval = 0.1 Arc Second)

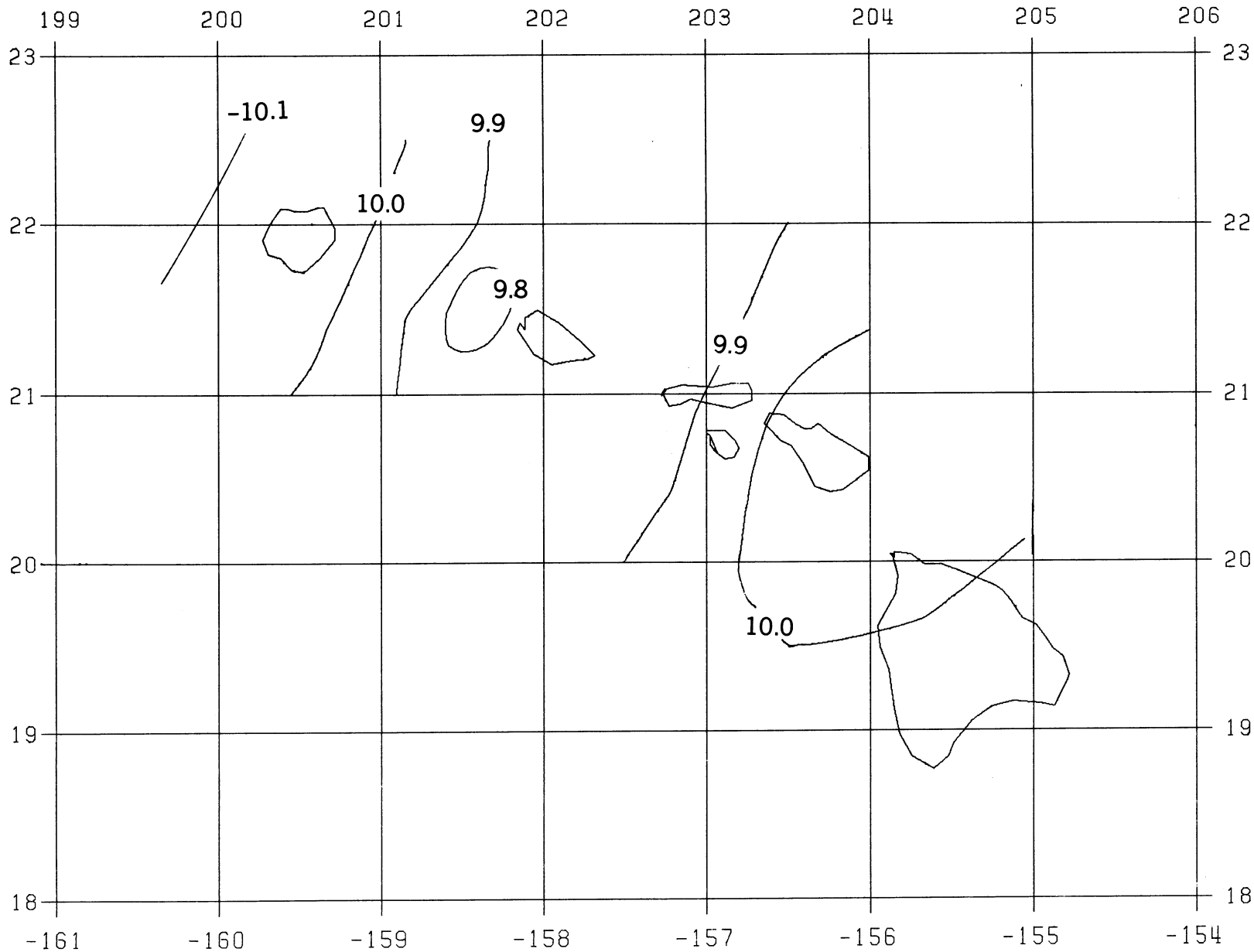

Figure 16.80. Contour Chart–Longitude Differences, WGS 84 Minus Old Hawaiian Datum (Contour Interval = 0.1 Arc Second)

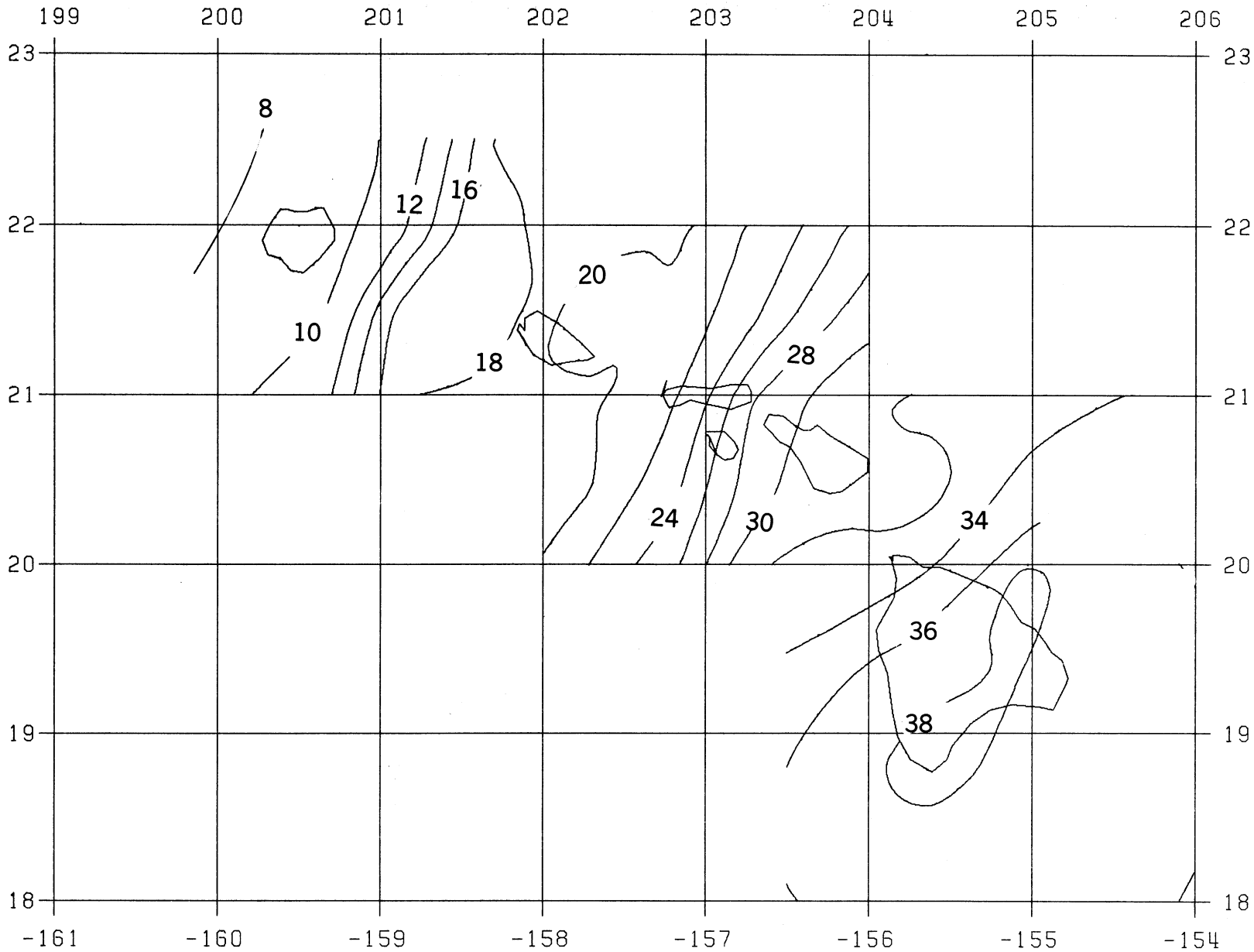

Figure 16.81. Contour Chart–Geodetic Height Differences, WGS 84 Minus Old Hawaiian Datum (Contour Interval = 2 Meters)

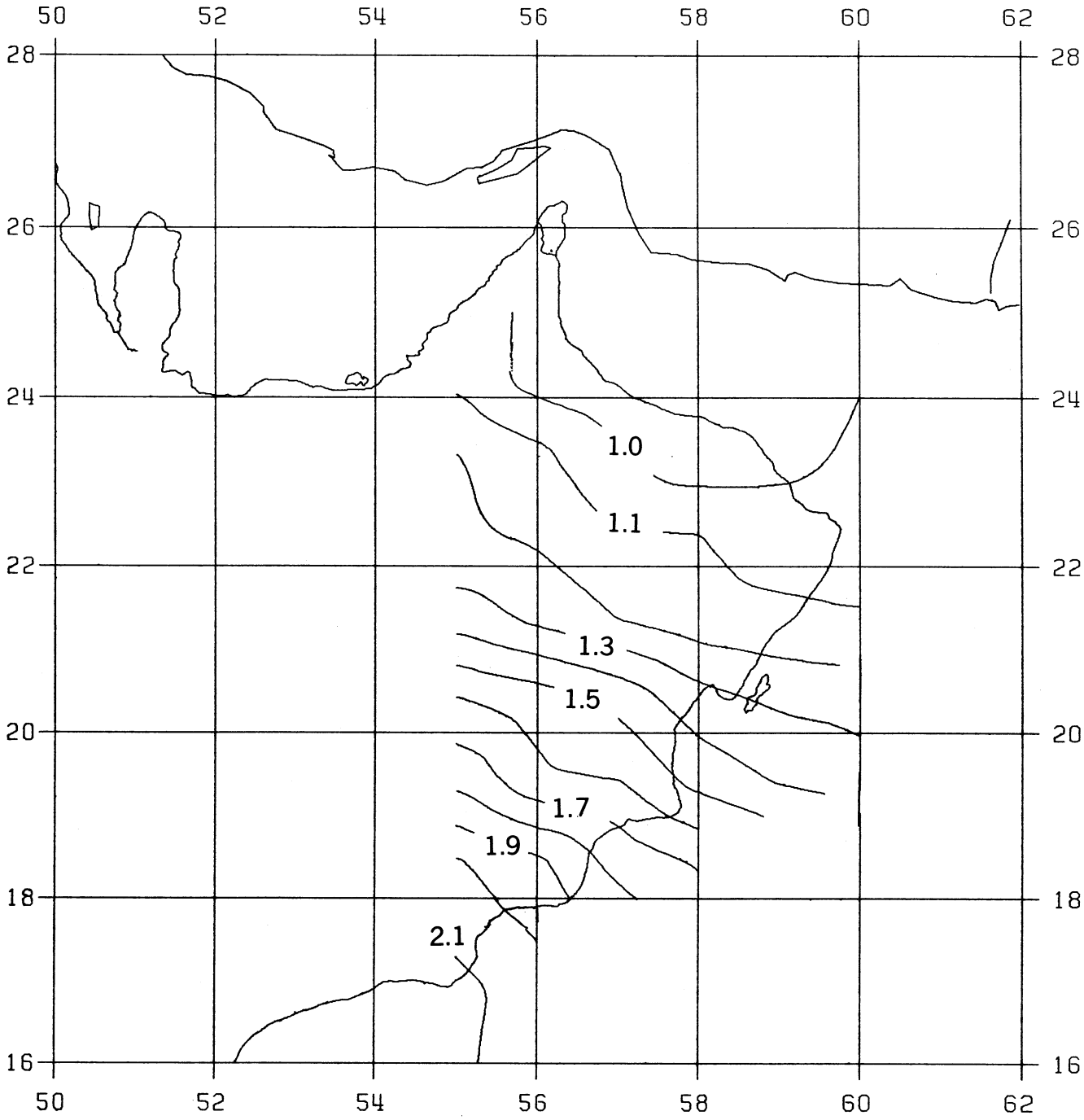

Figure 16.82. Contour Chart–Latitude Differences, WGS 84 Minus Oman Datum
(Contour Interval = 0.1 Arc Second)

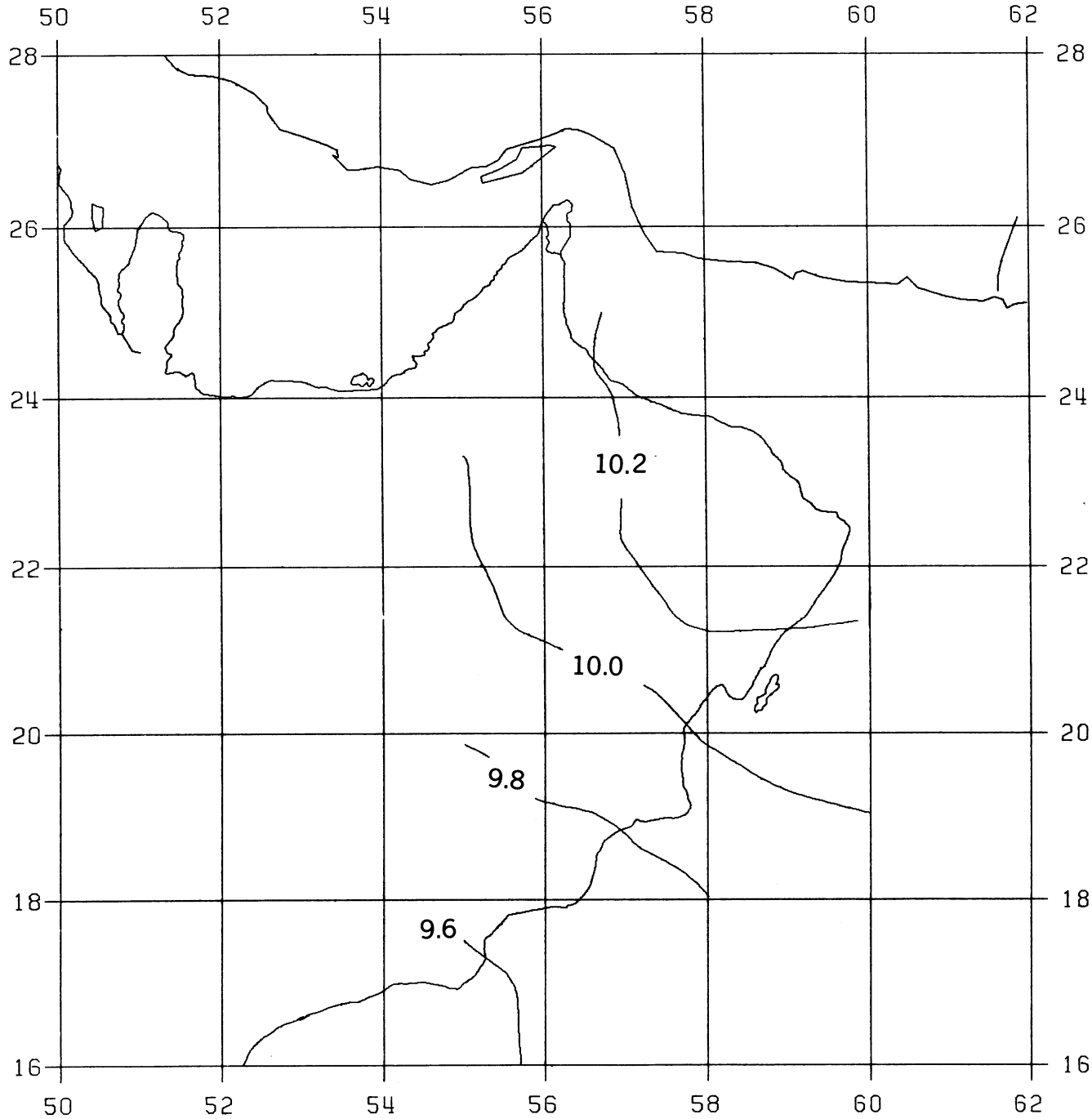

Figure 16.83. Contour Chart – Longitude Differences, WGS 84 Minus Oman Datum
(Contour Interval = 0.2 Arc Second)

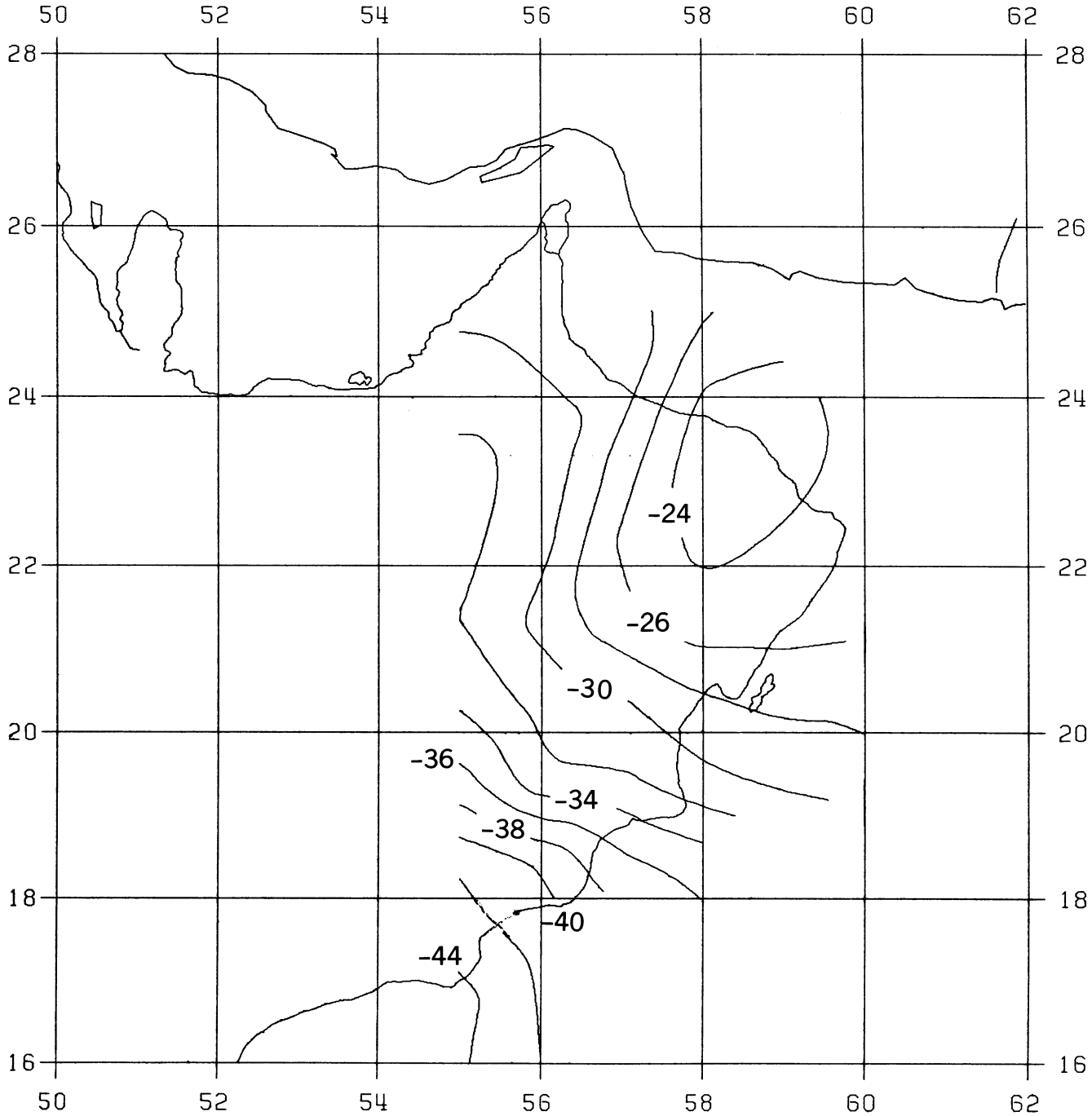

Figure 16.84. Contour Chart–Geodetic Height Differences, WGS 84 Minus Oman Datum (Contour Interval = 2 Meters)

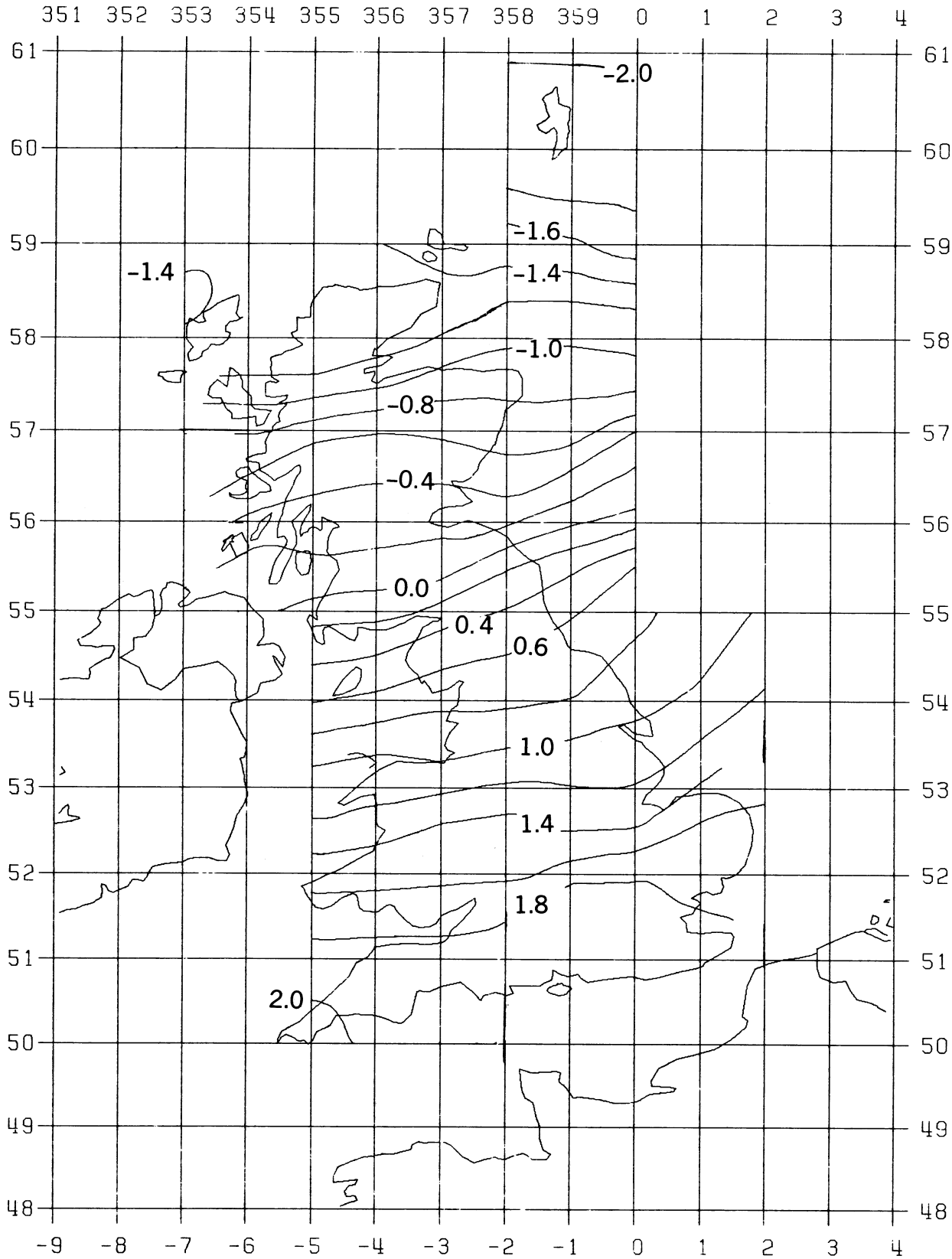

Figure 16.85. Contour Chart - Latitude Differences, WGS 84 Minus Ordnance Survey of Great Britain 1936 Datum (Contour Interval = 0.2 Arc Second)

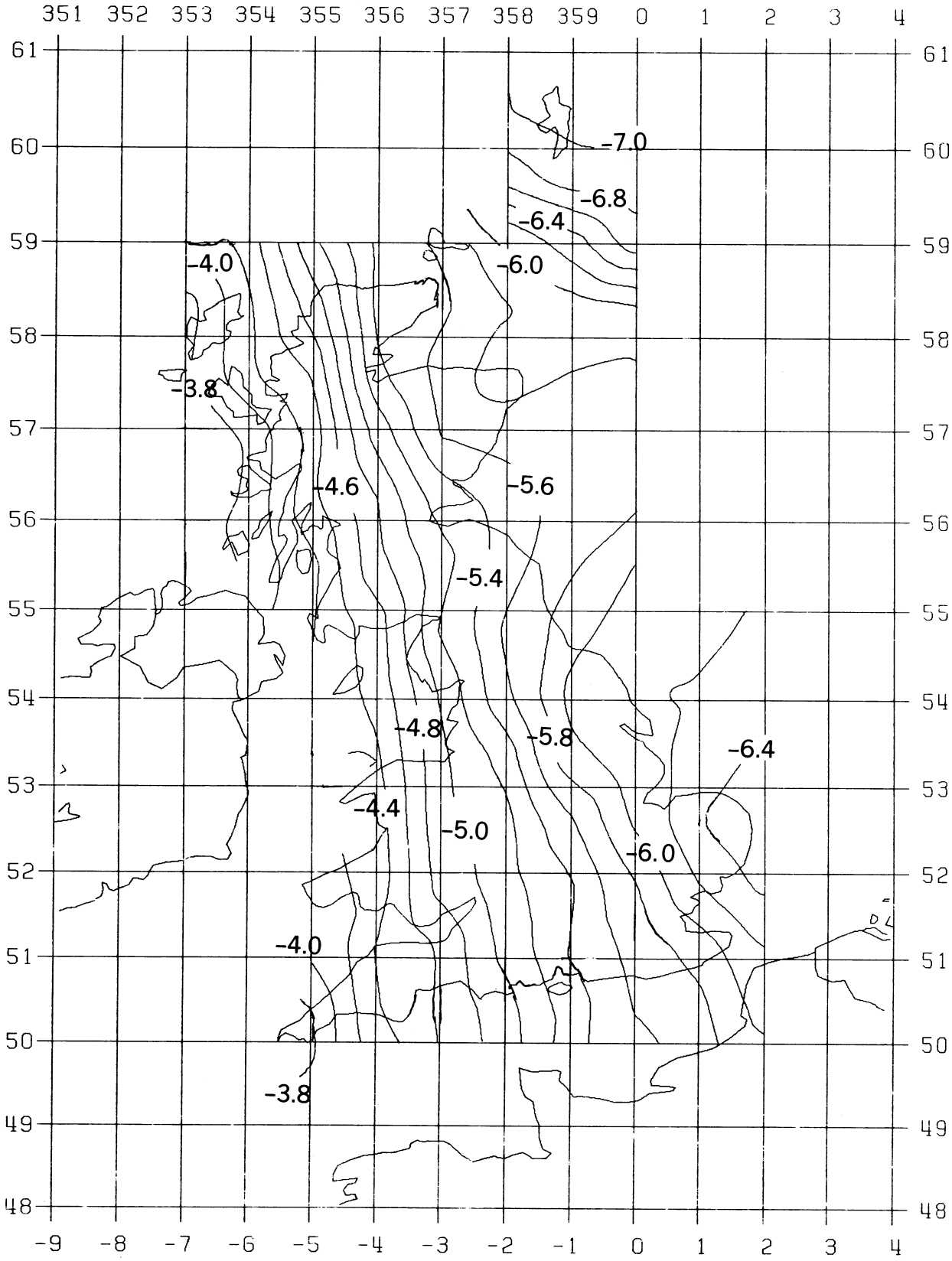

Figure 16.86. Contour Chart–Longitude Differences, WGS 84 Minus Ordnance Survey of Great Britain 1936 Datum (Contour Interval = 0.2 Arc Second)

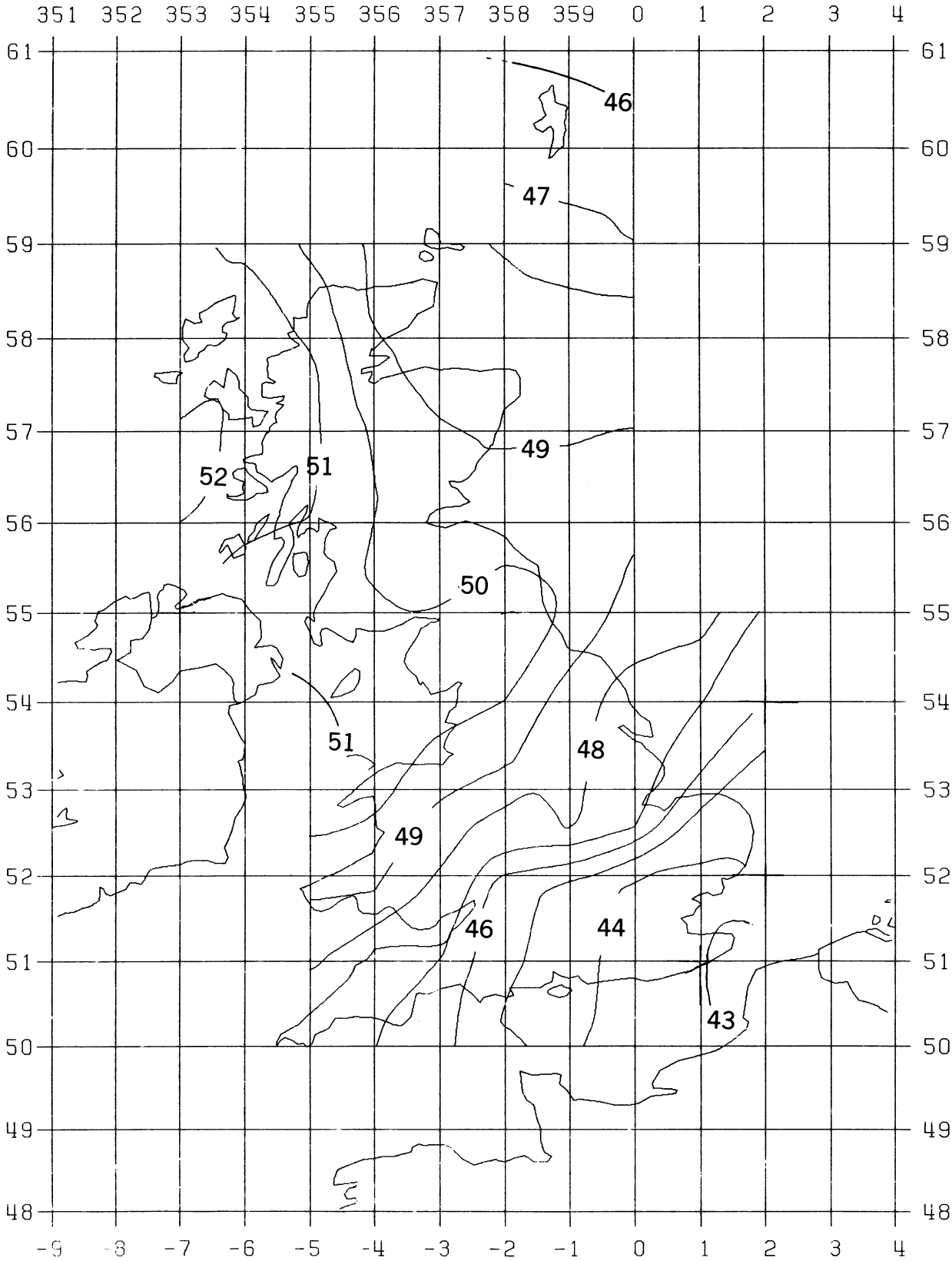

Figure 16.87. Contour Chart–Geodetic Height Differences, WGS 84 Minus Ordnance Survey of Great Britain 1936 Datum (Contour Interval = 1 Meter)

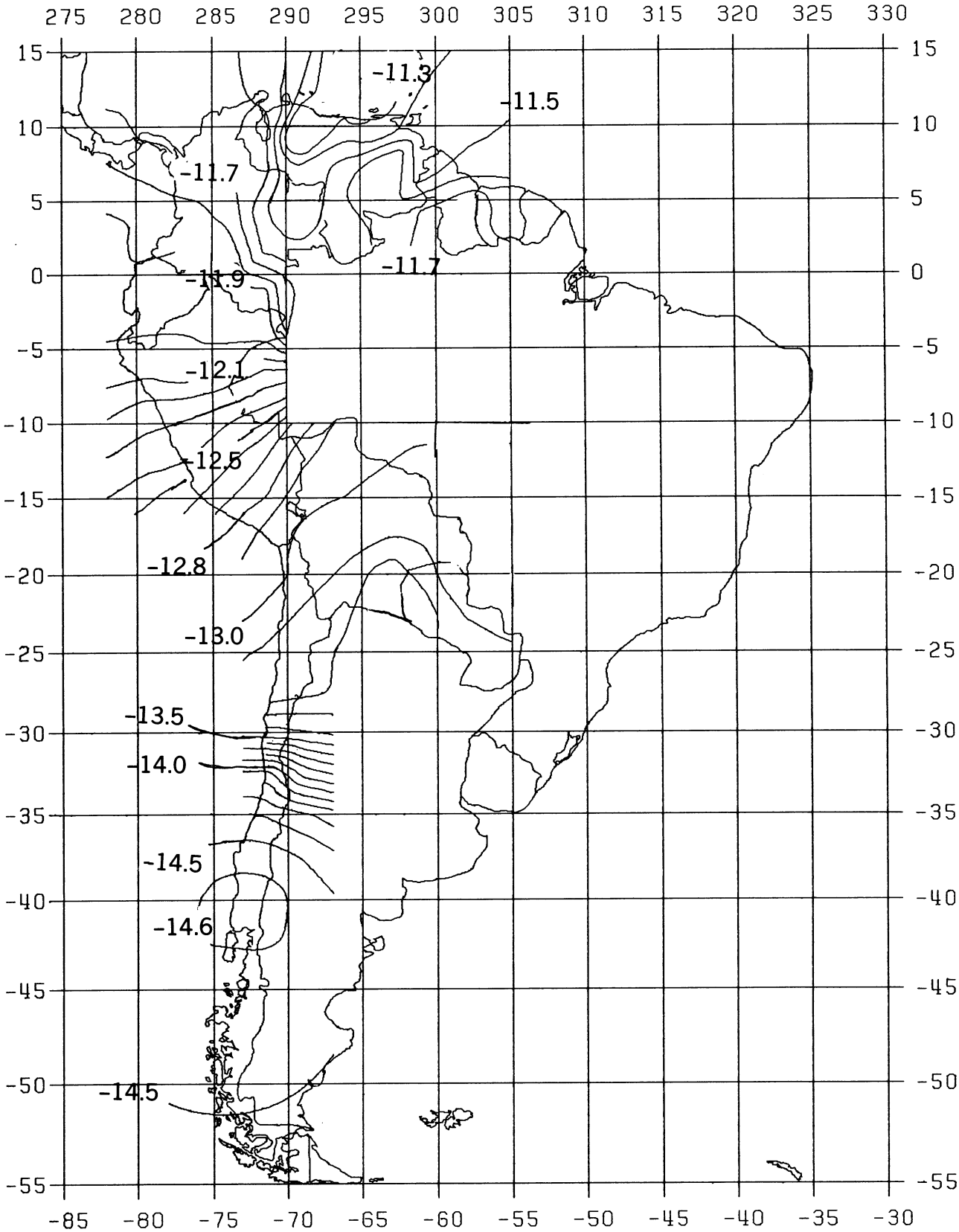

Figure 16.88. Contour Chart – Latitude Differences, WGS 84 Minus Provisional South American Datum 1956 (Contour Interval = 0.1 Arc Second)

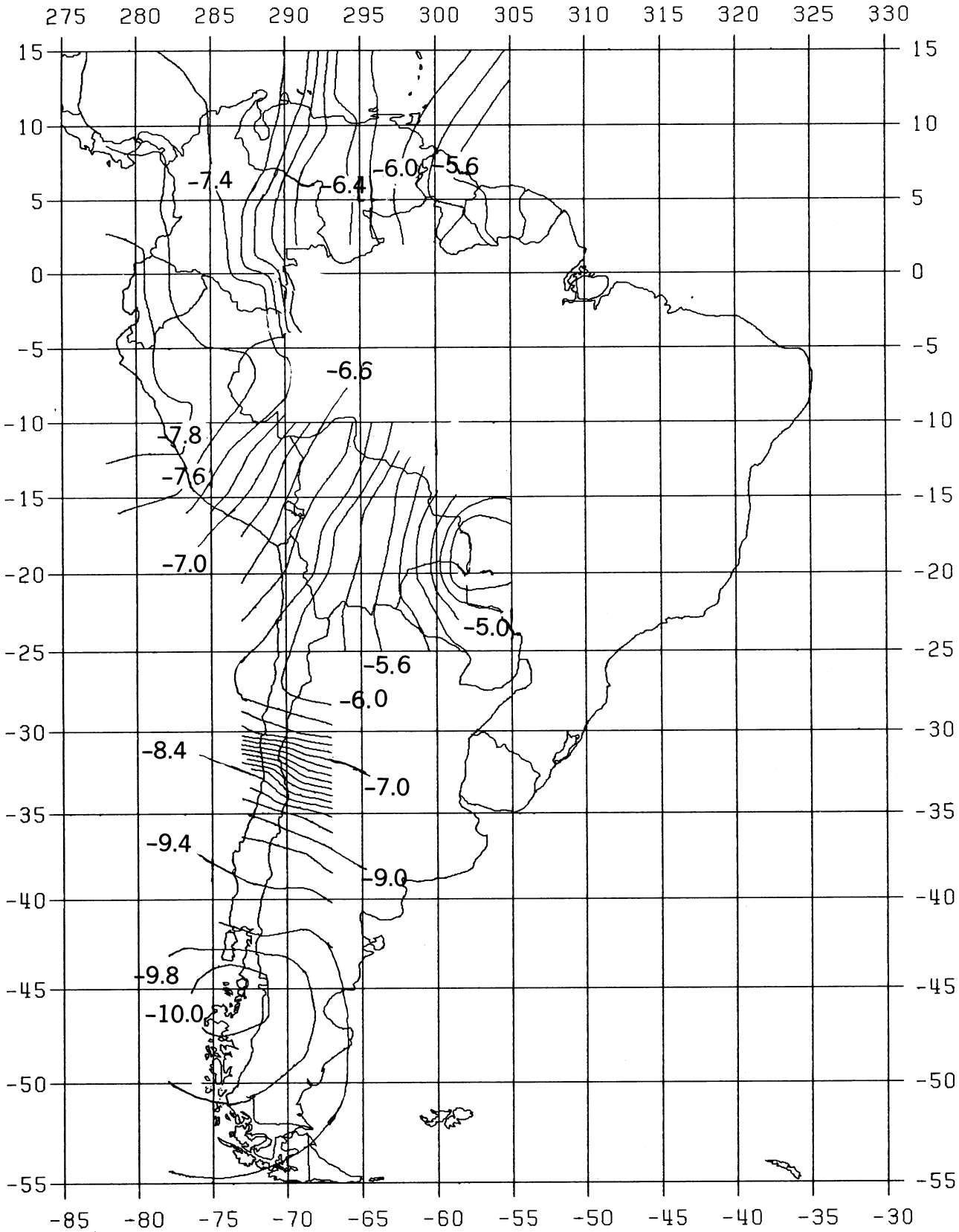

Figure 16.89. Contour Chart-Longitude Differences, WGS 84 Minus Provisional South American Datum 1956 (Contour Interval = 0.2 Arc Second)

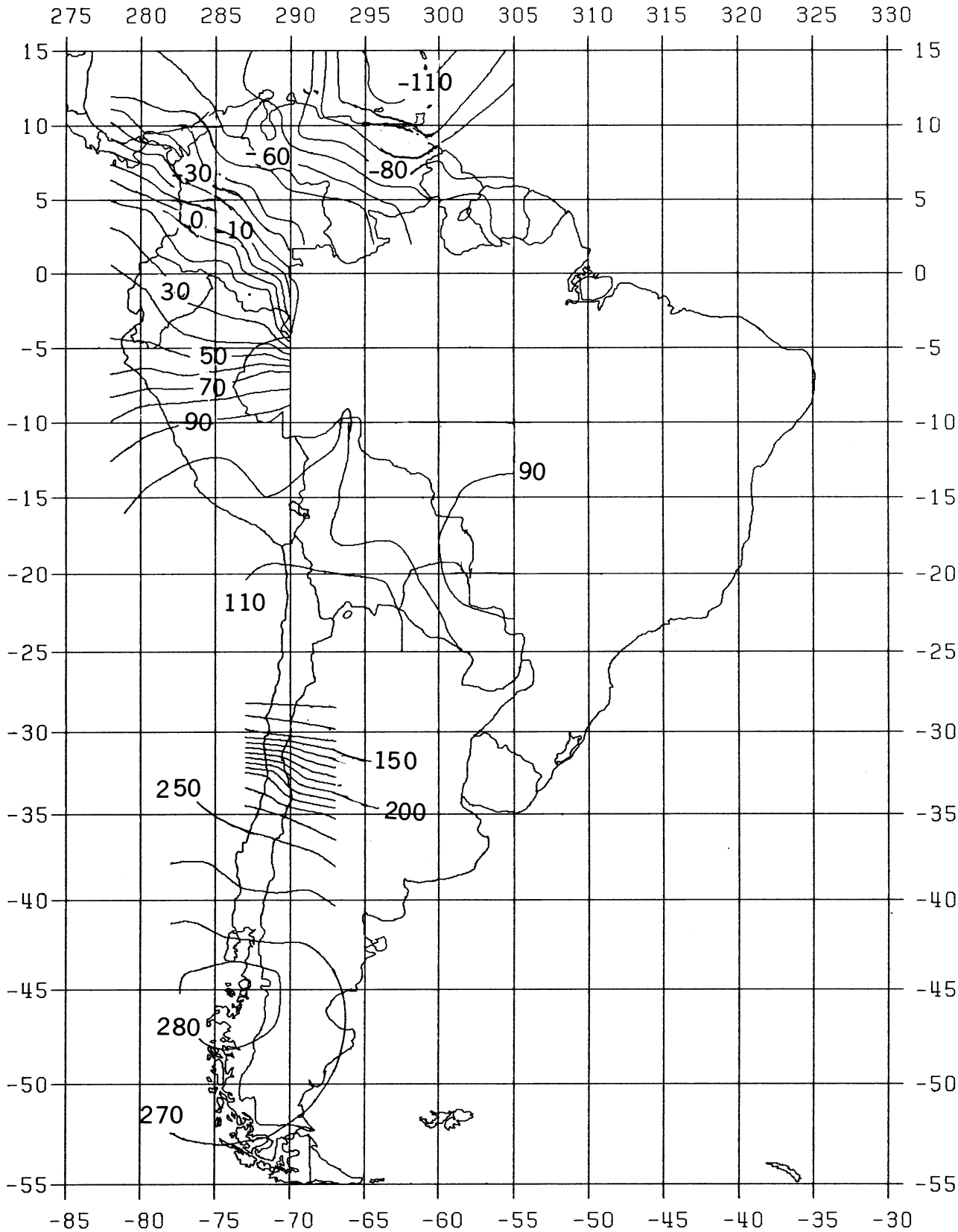

Figure 16.90. Contour Chart–Geodetic Height Differences, WGS 84 Minus Provisional South American Datum 1956 (Contour Interval = 10 Meters)

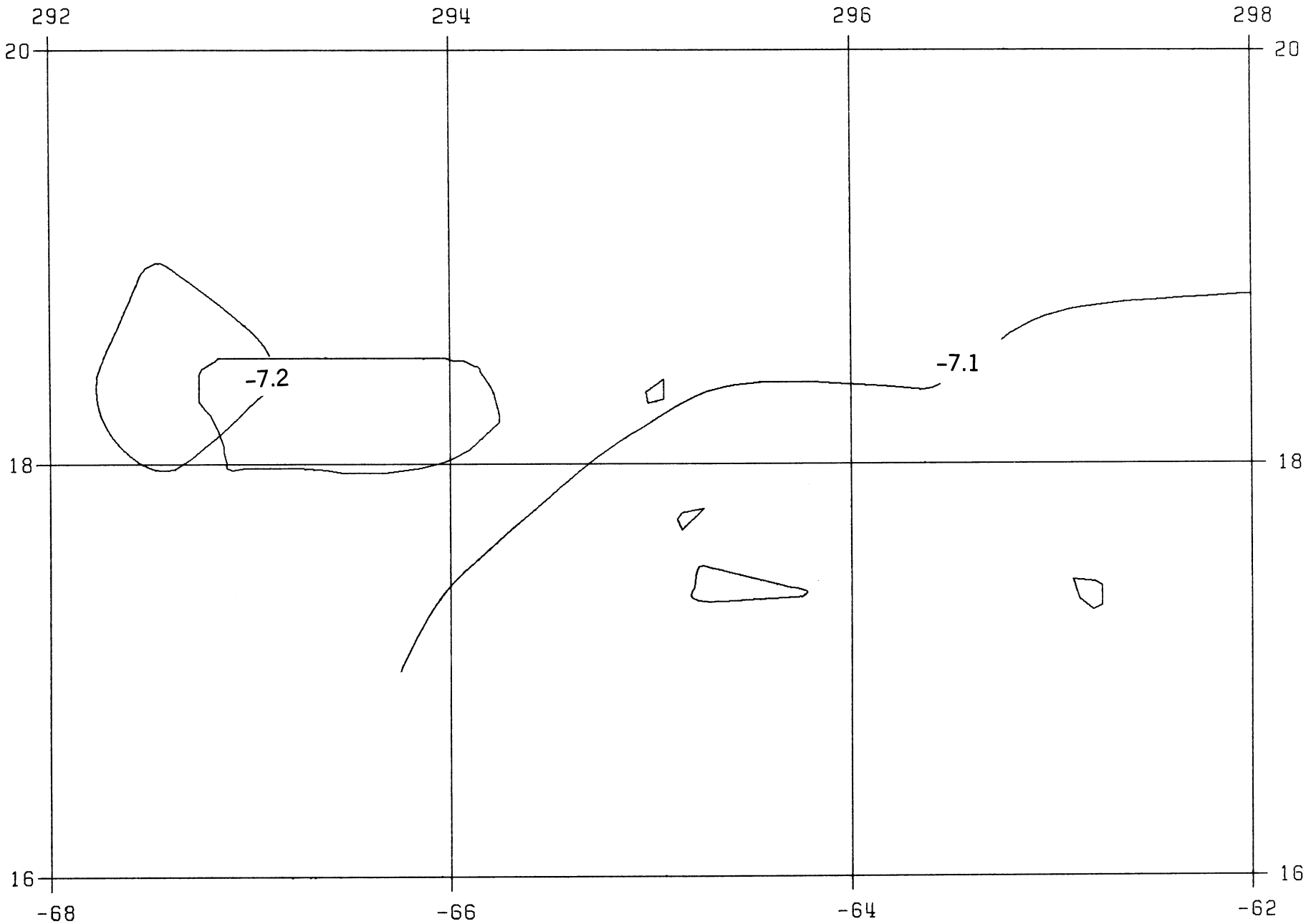

Figure 16.91. Contour Chart–Latitude Differences, WGS 84 Minus Puerto Rico Datum (Contour Interval = 0.1 Arc Second)

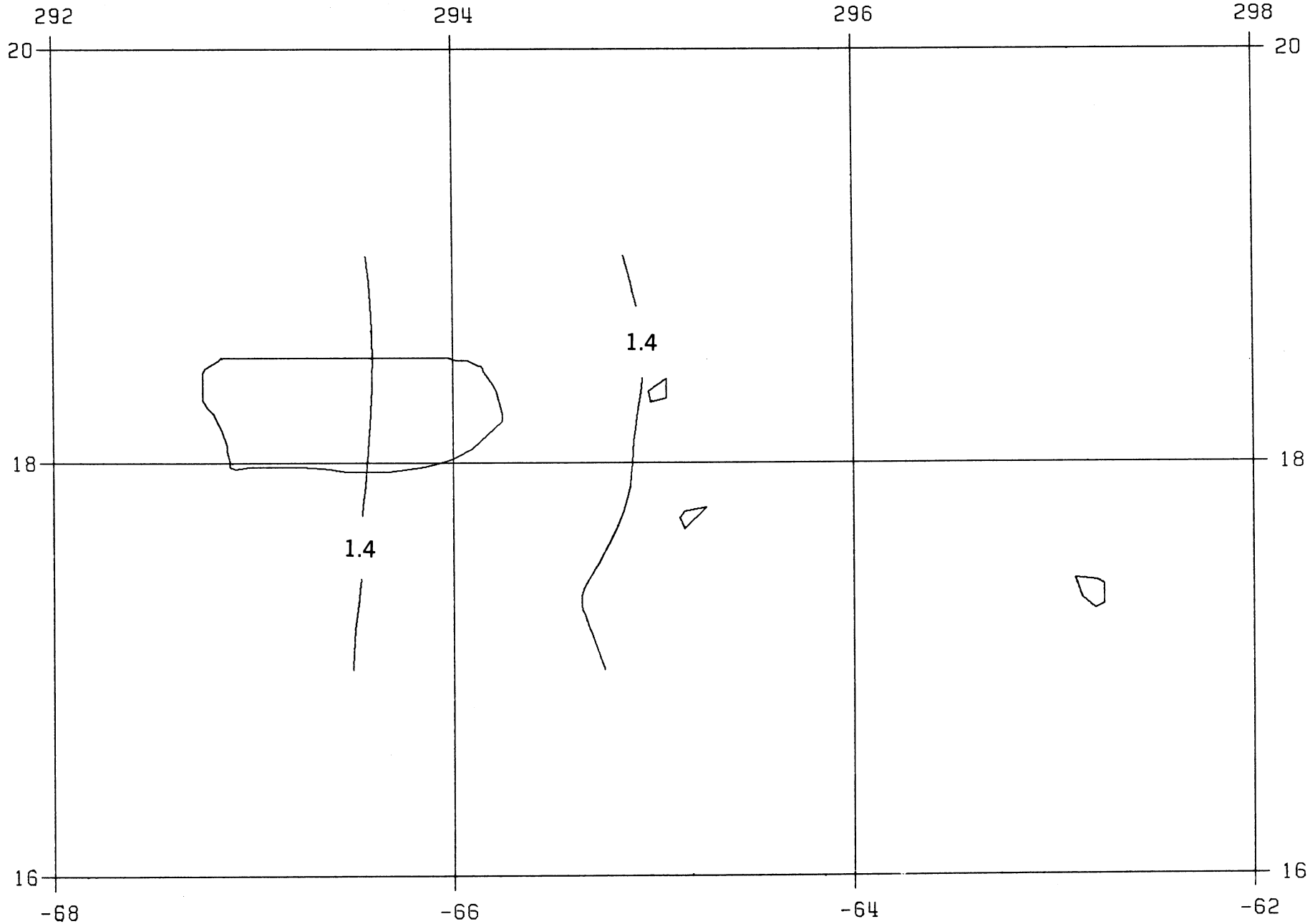

Figure 16.92. Contour Chart–Longitude Differences, WGS 84 Minus Puerto Rico Datum (Contour Interval = 0.1 Arc Second)

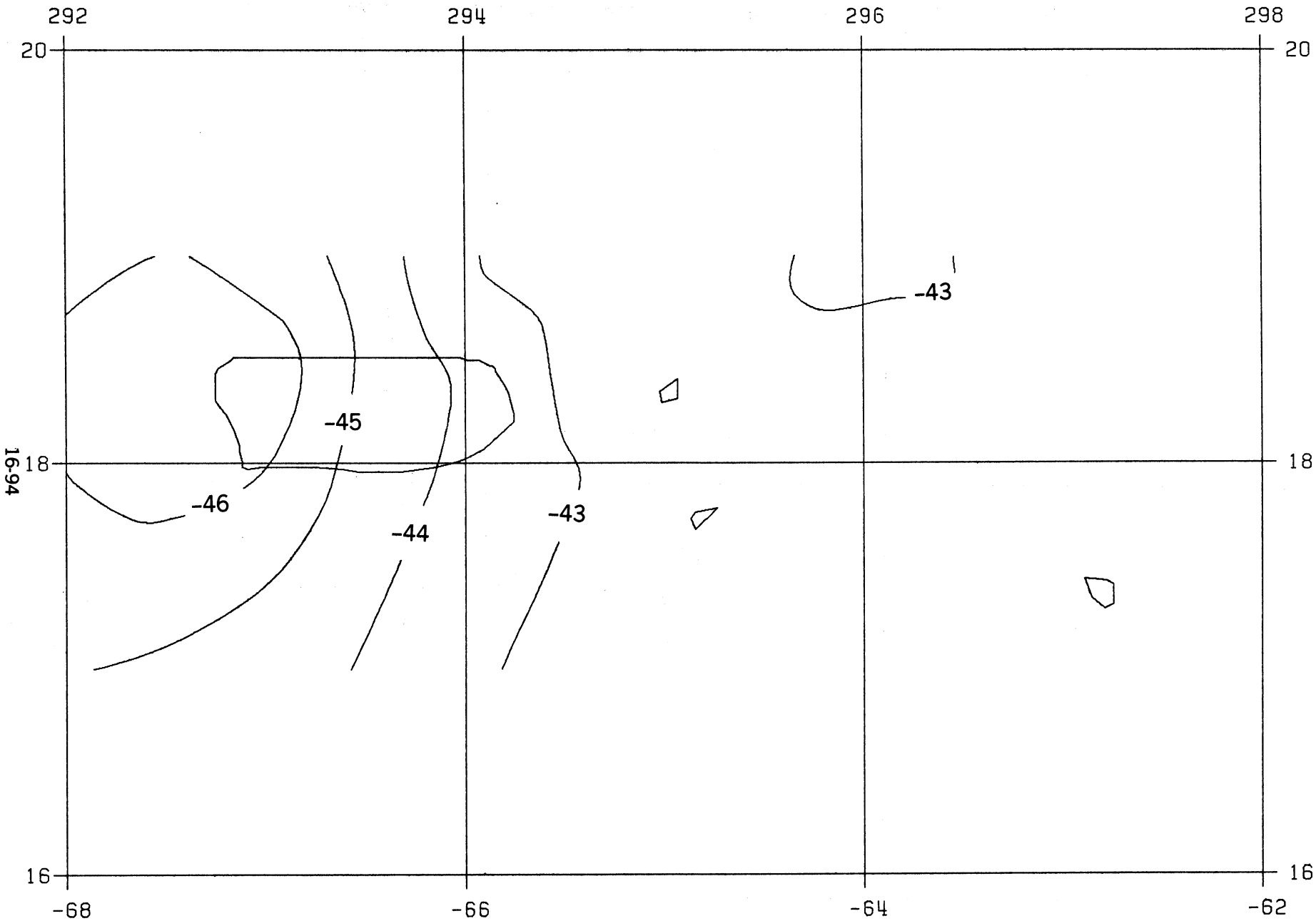

Figure 16.93. Contour Chart–Geodetic Height Differences, WGS 84 Minus Puerto Rico Datum (Contour Interval = 1 Meter)

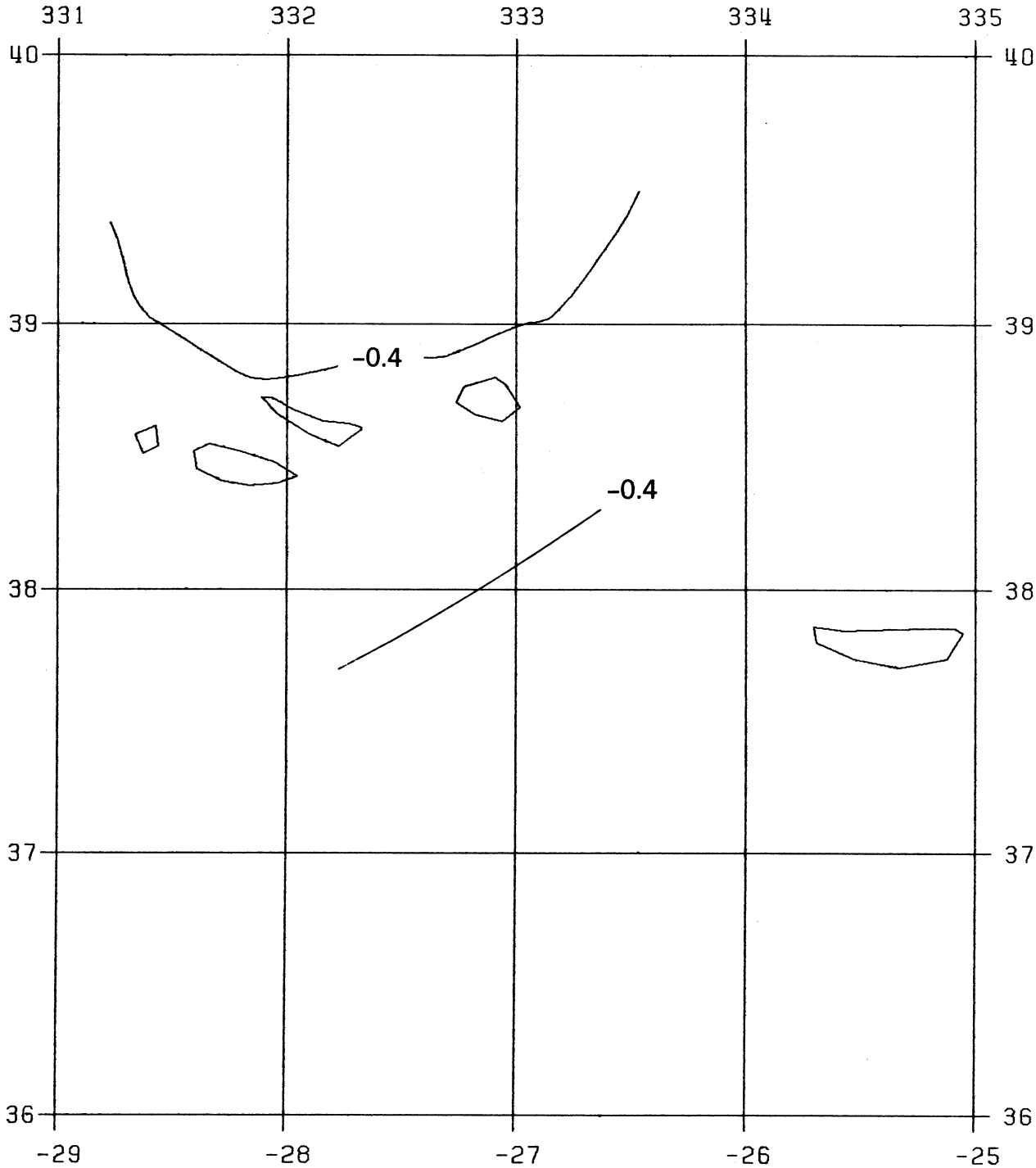

Figure 16.94. Contour Chart–Latitude Differences, WGS 84 Minus Southwest Base Datum (Contour Interval = 0.1 Arc Second)

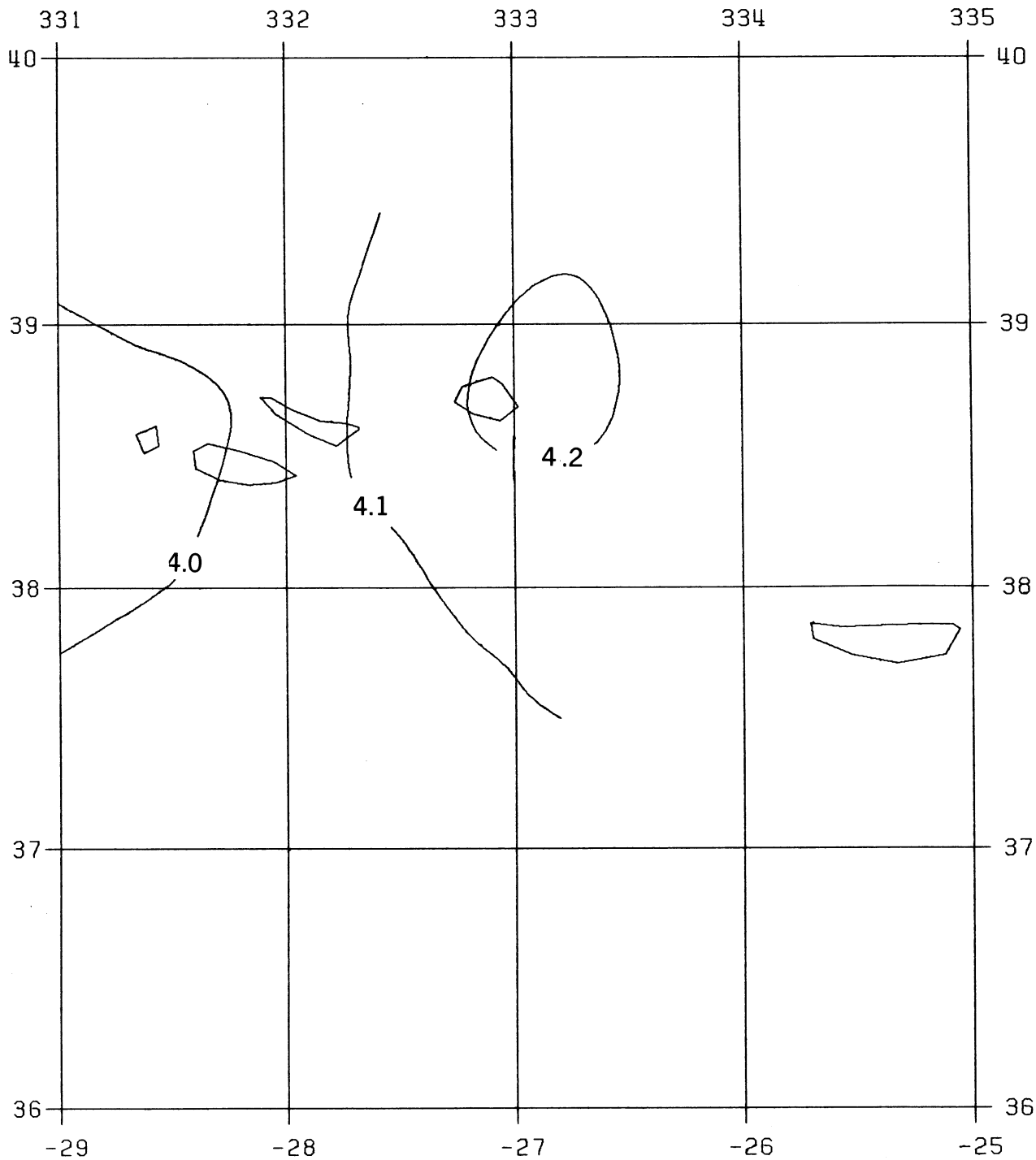

Figure 16.95. Contour Chart - Longitude Differences, WGS 84 Minus Southwest Base Datum (Contour Interval = 0.1 Arc Second)

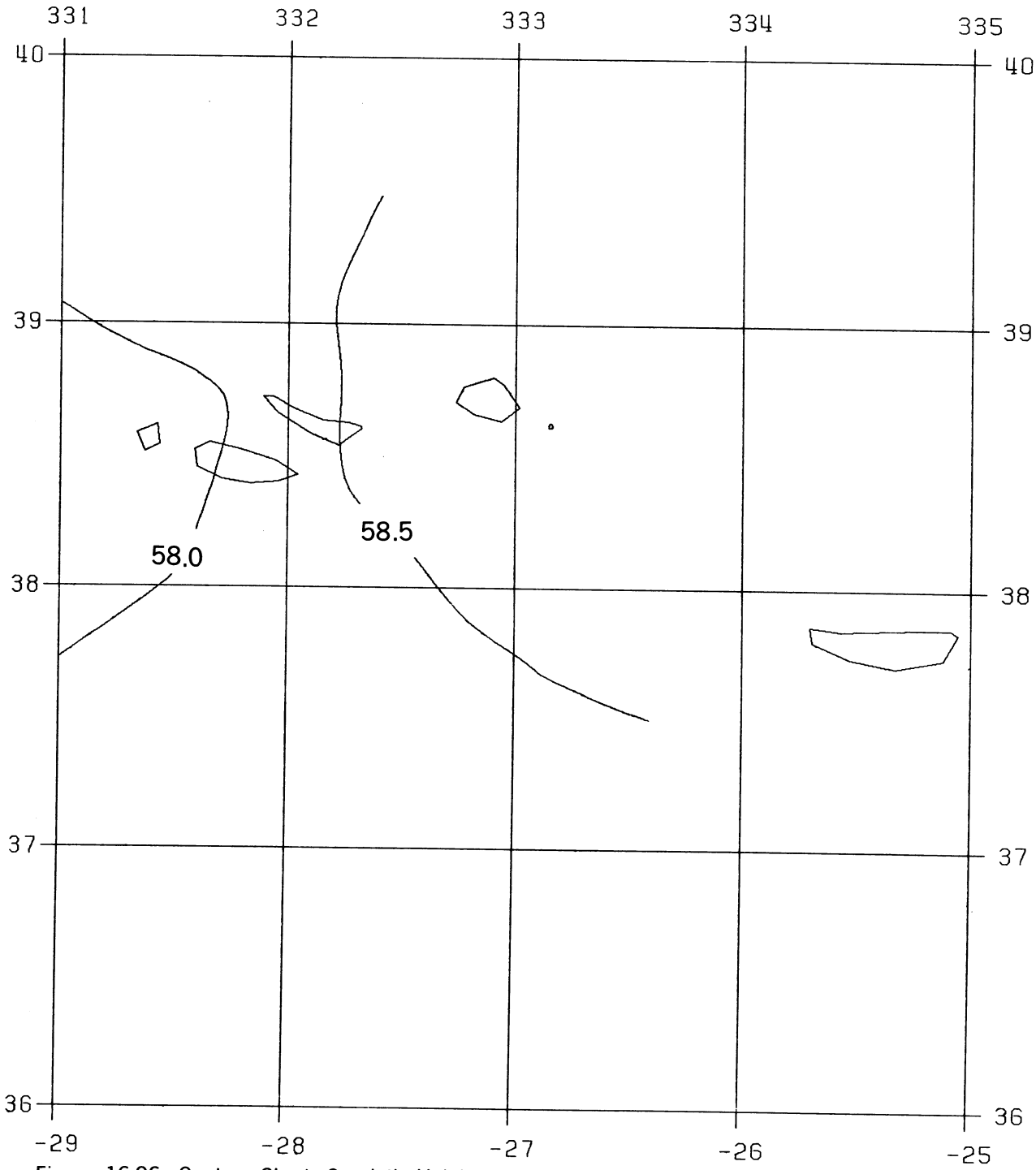

Figure 16.96. Contour Chart–Geodetic Height Differences, WGS 84 Minus Southwest Base Datum (Contour Interval = 0.5 Meter)

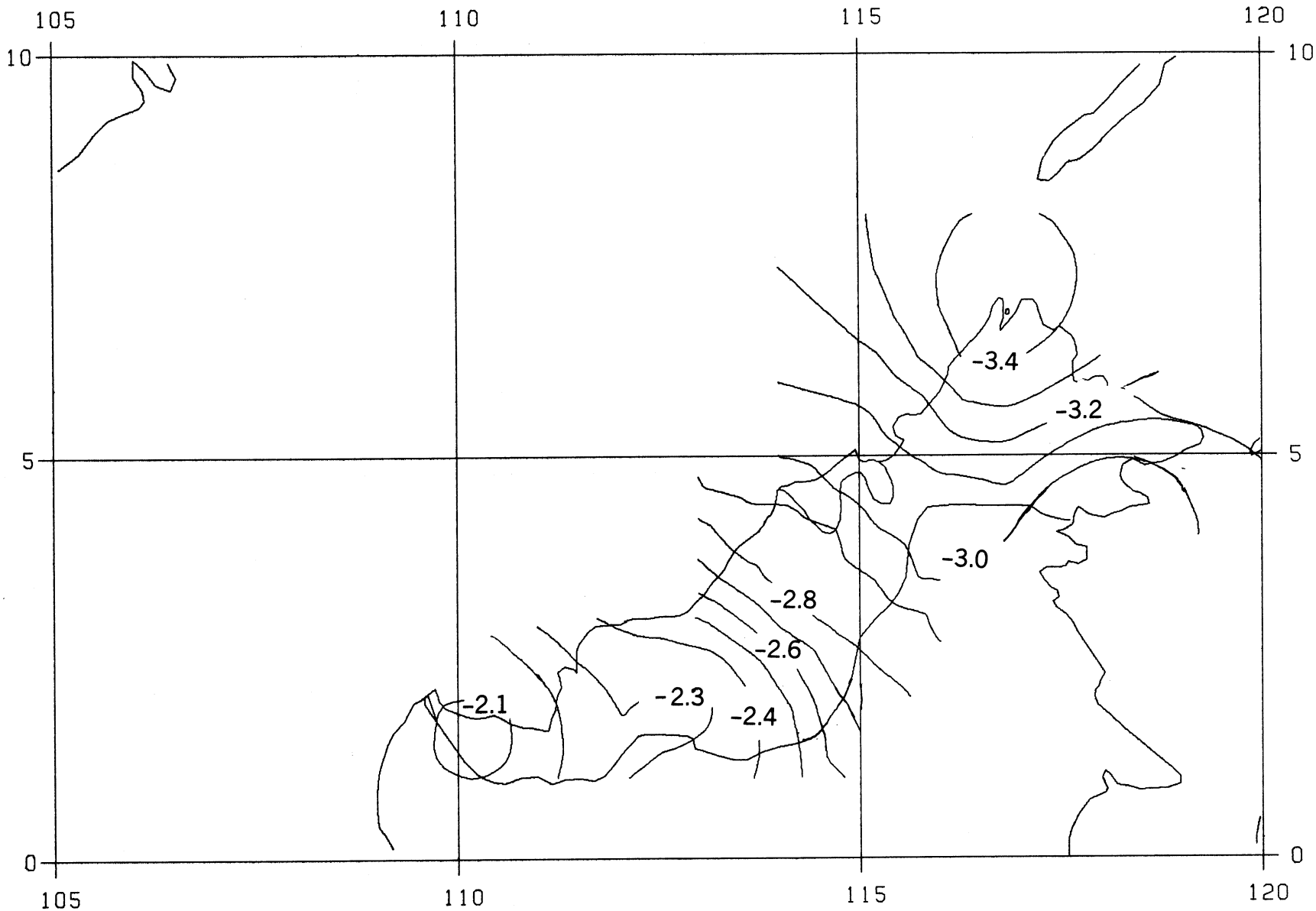

Figure 16.97. Contour Chart - Latitude Differences, WGS 84 Minus Timbalai Datum 1948 (Contour Interval = 0.1 Arc Second)

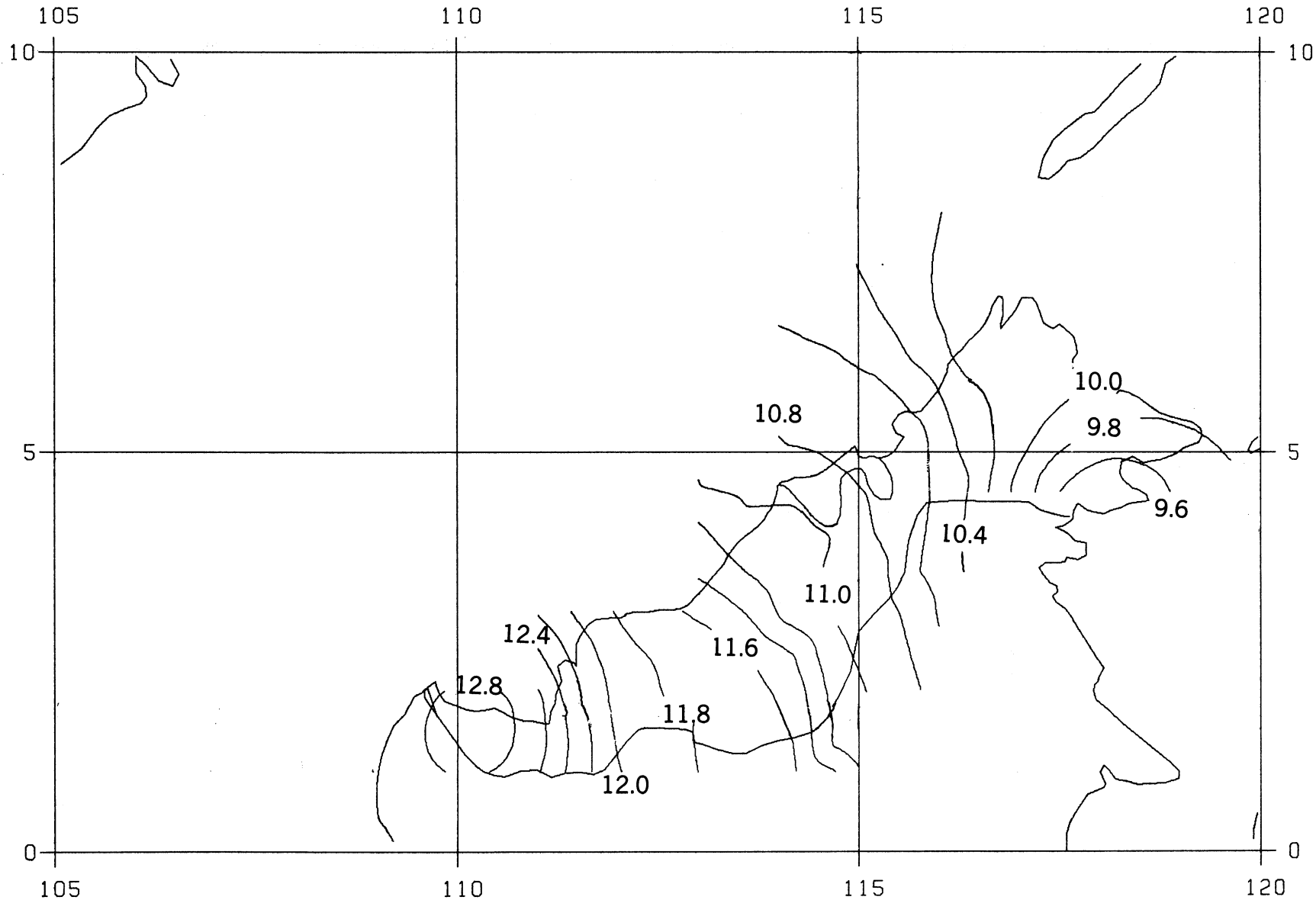

Figure 16.98. Contour Chart - Longitude Differences, WGS 84 Minus Timbalai Datum 1948 (Contour Interval = 0.2 Arc Second)

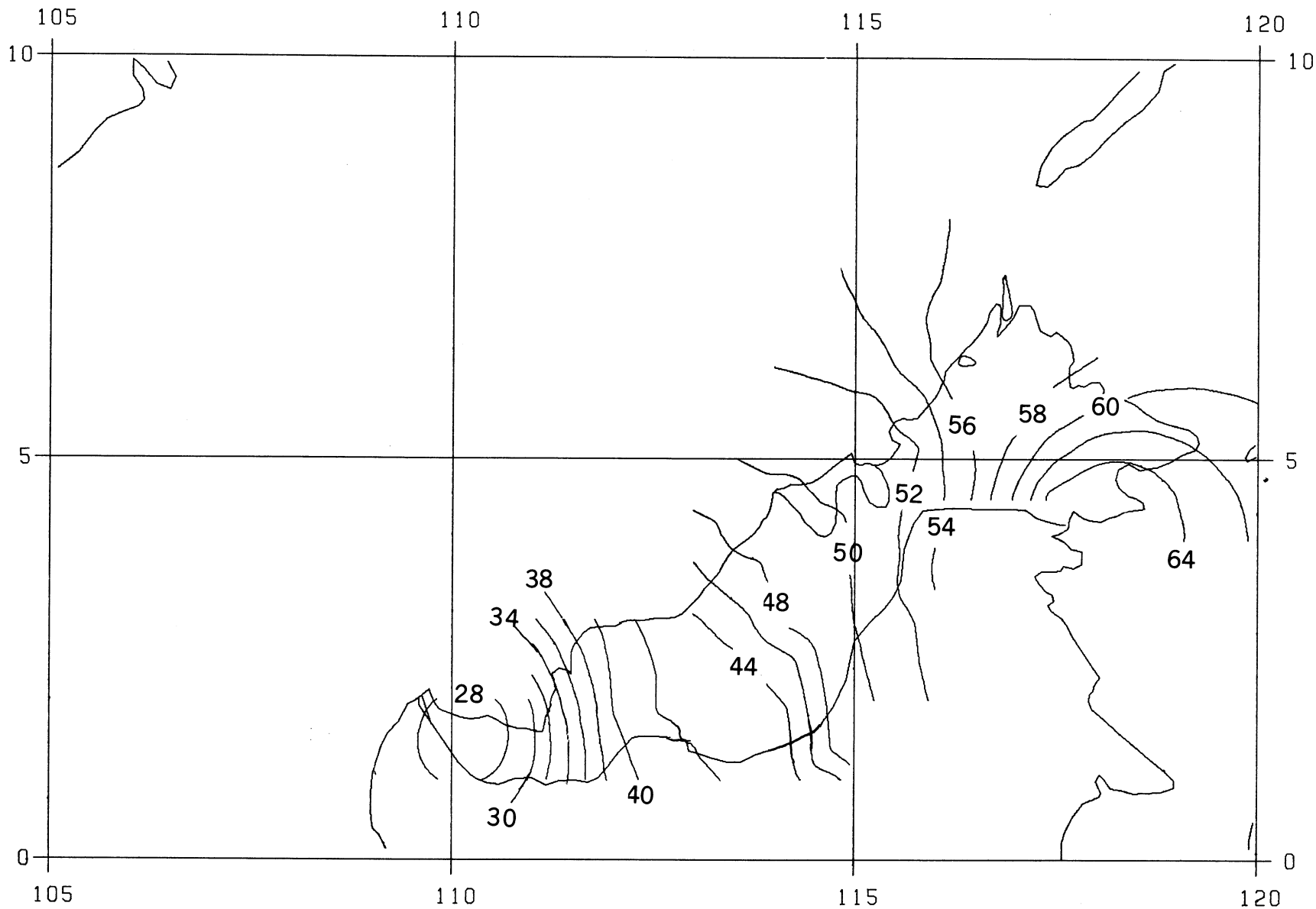

Figure 16.99. Contour Chart-Geodetic Height Differences, WGS 84 Minus Timbalai Datum 1948 (Contour Interval = 2 Meters)

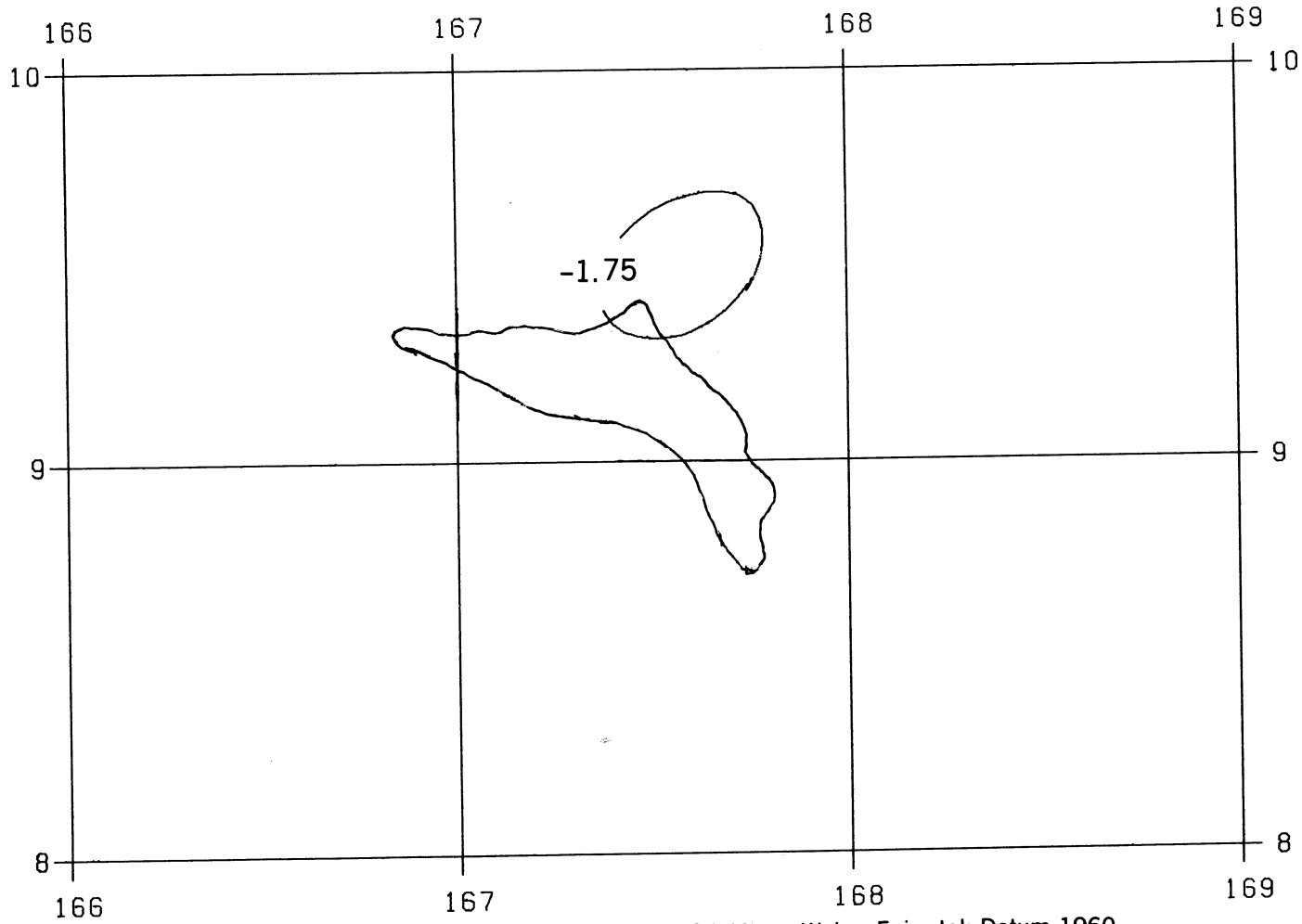

Figure 16.100. Contour Chart-Latitude Differences, WGS 84 Minus Wake-Eniwetok Datum 1960 (Contour Interval = 0.05 Arc Second)

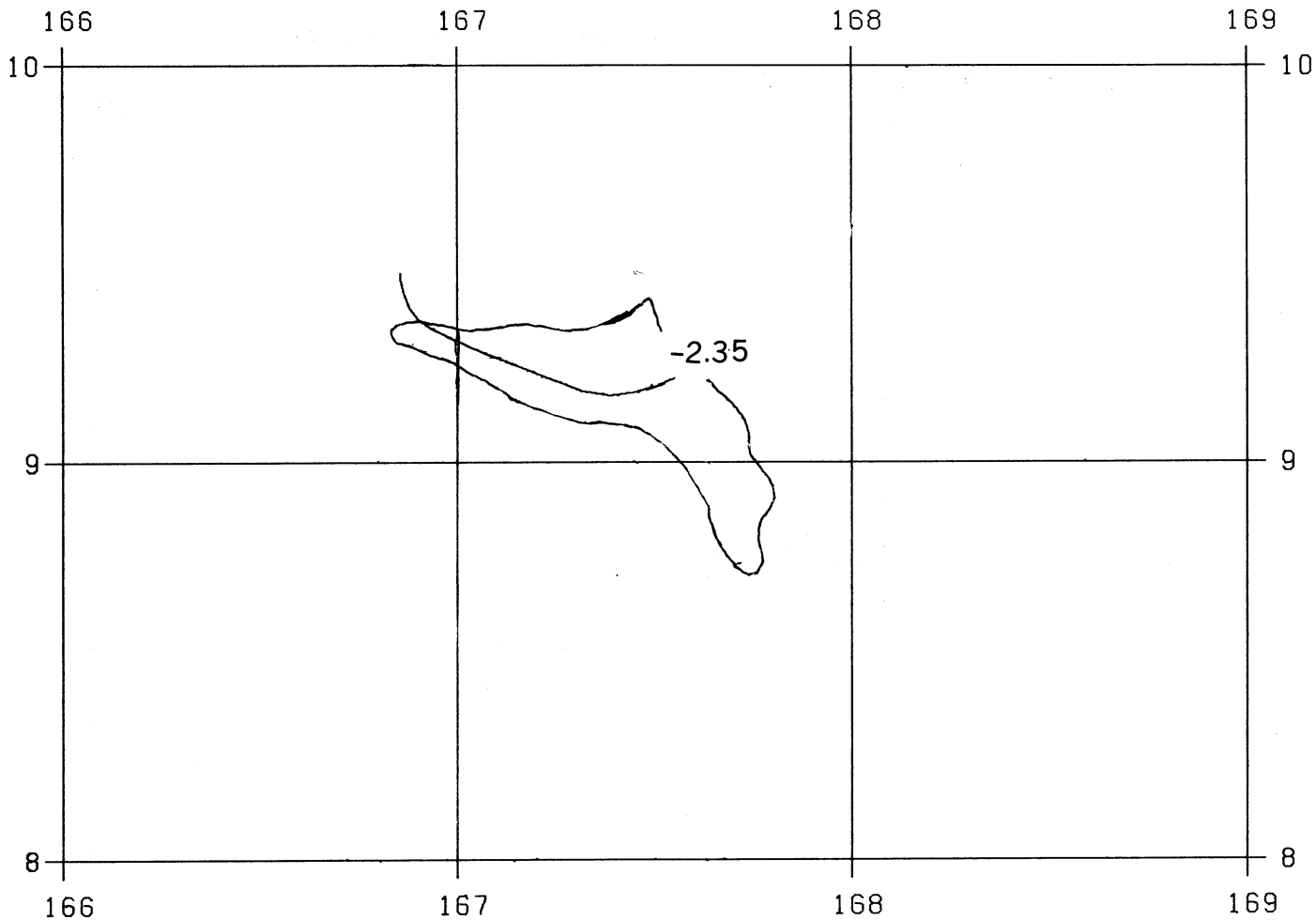

Figure 16.101. Contour Chart-Longitude Differences, WGS 84 Minus Wake-Eniwetok Datum 1960 (Contour Interval = 0.05 Arc Second)

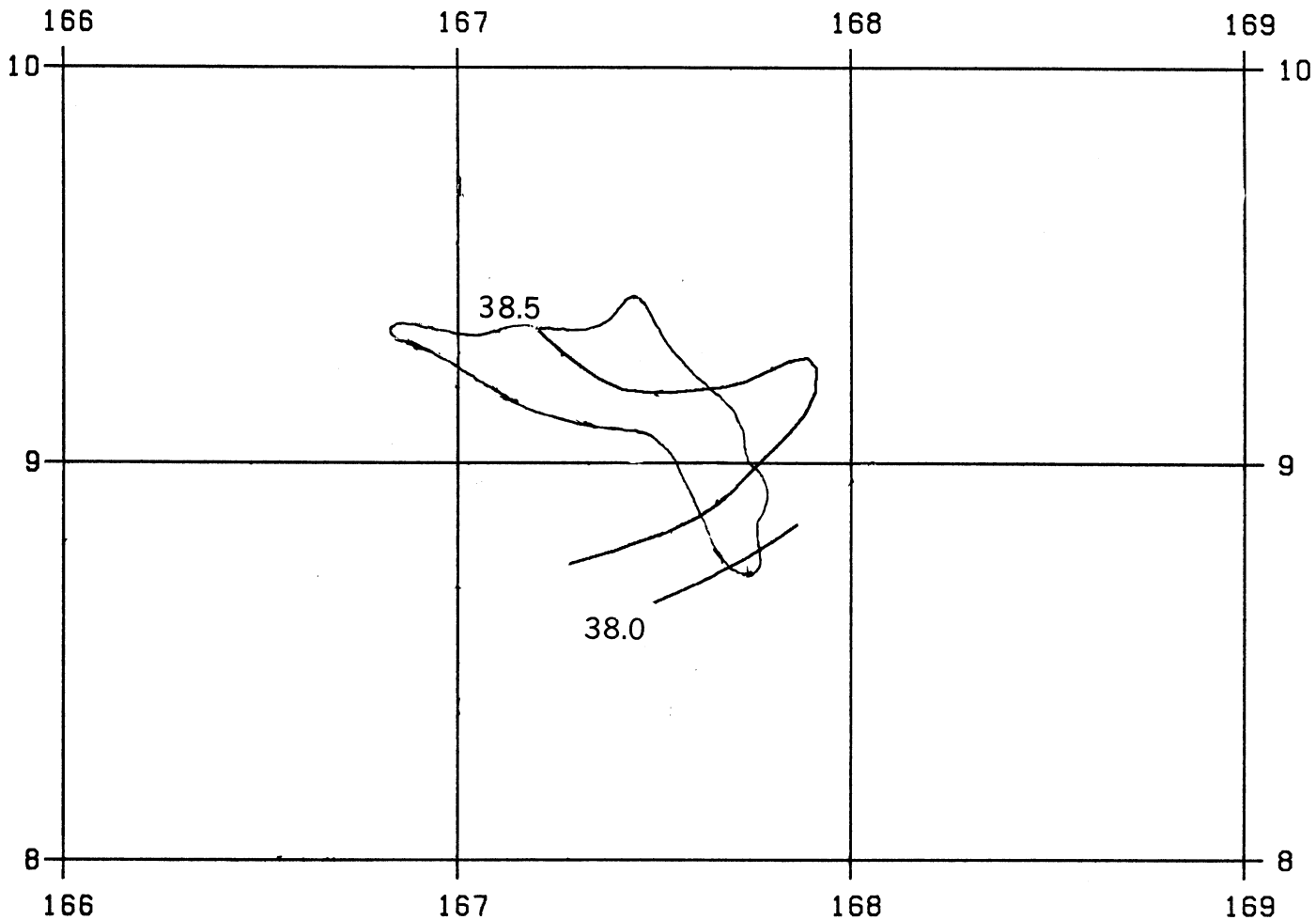

Figure 16.102. Contour Chart-Geodetic Height Differences, WGS 84 Minus Wake-Eniwetok Datum 1960 (Contour Interval = 0.5 Meter)

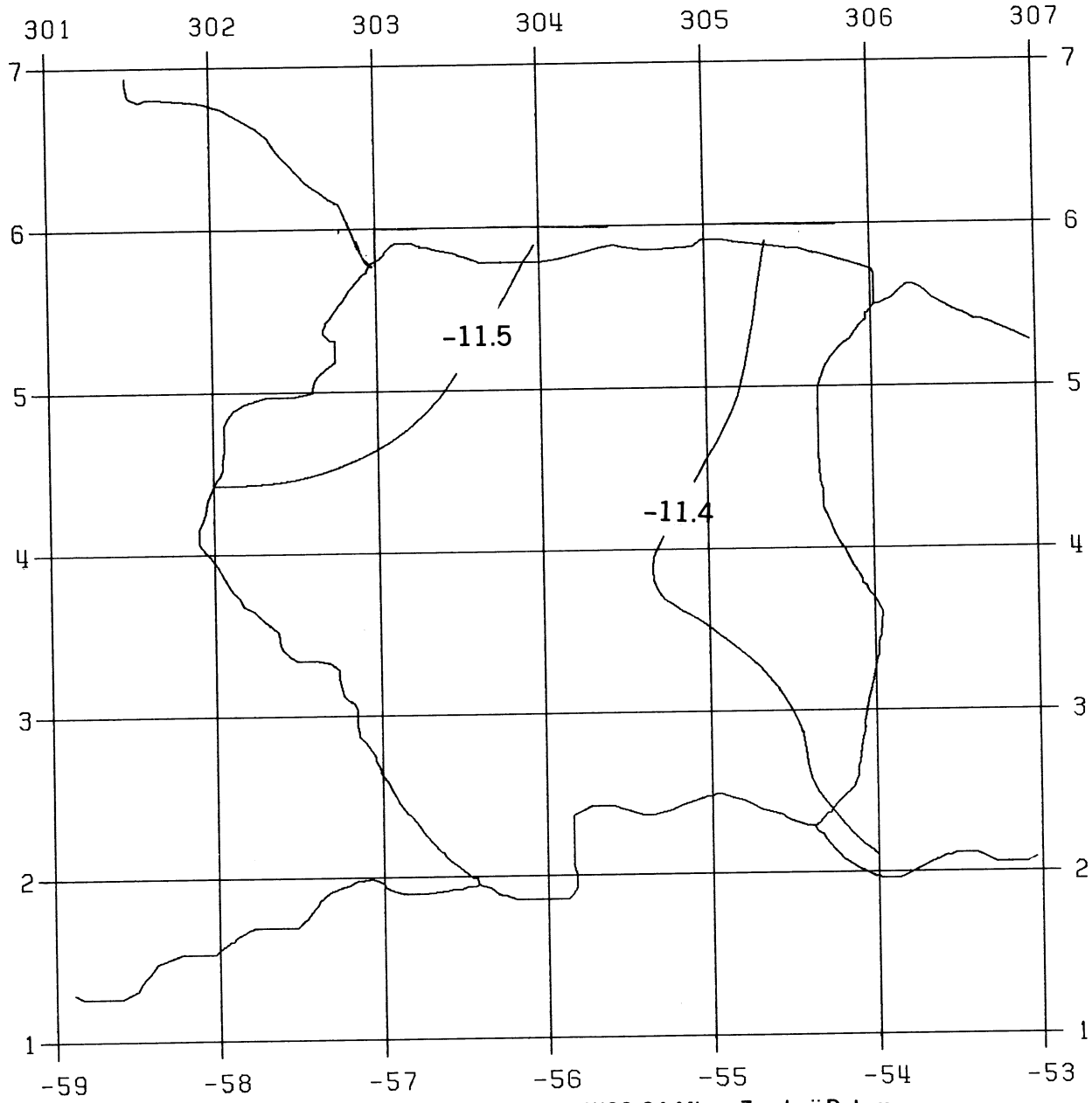

Figure 16.103. Contour Chart–Latitude Differences, WGS 84 Minus Zanderij Datum (Contour Interval = 0.1 Arc Second)

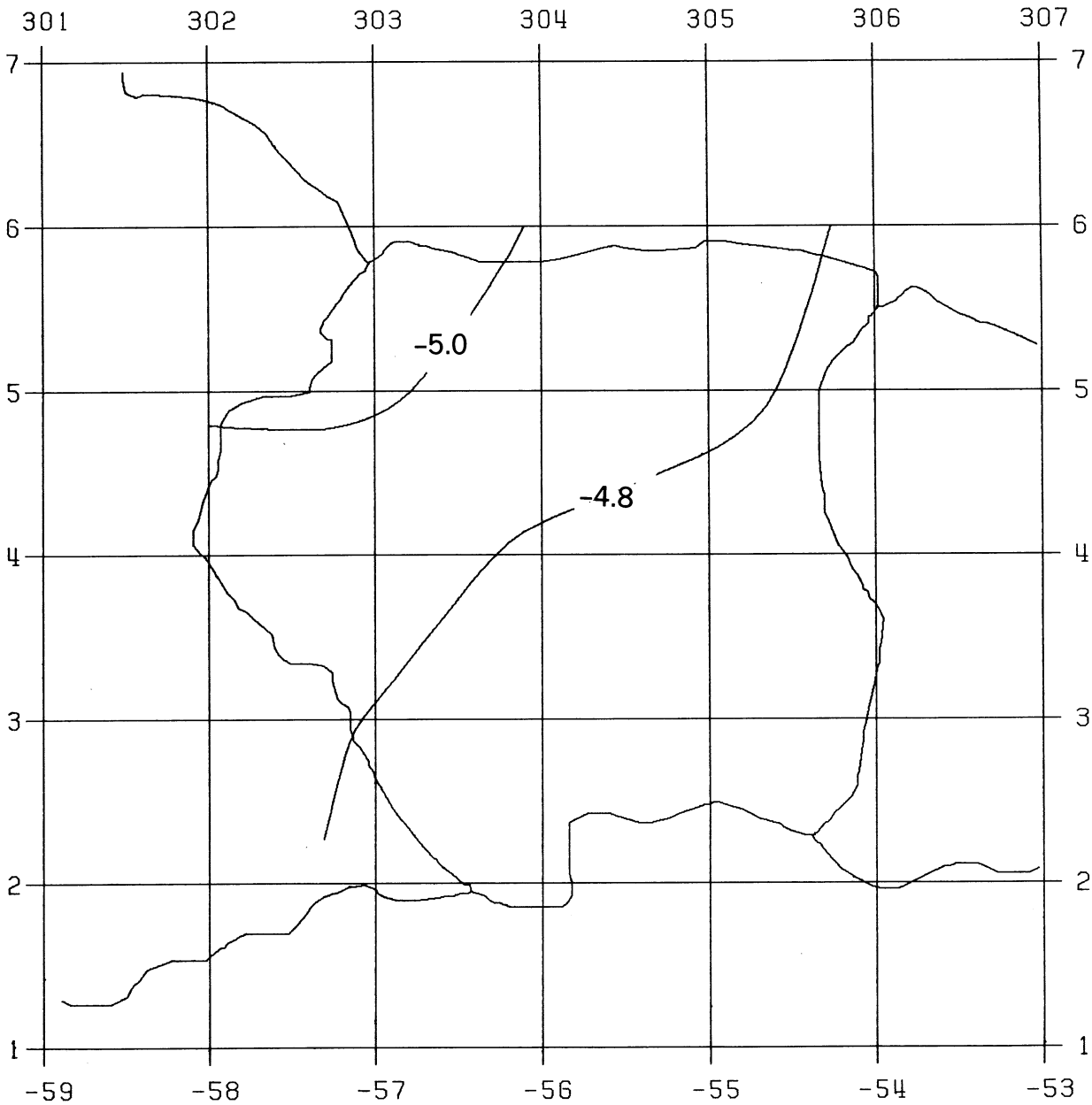

Figure 16.104. Contour Chart - Longitude Differences, WGS 84 Minus Zanderij Datum (Contour Interval = 0.2 Arc Second)

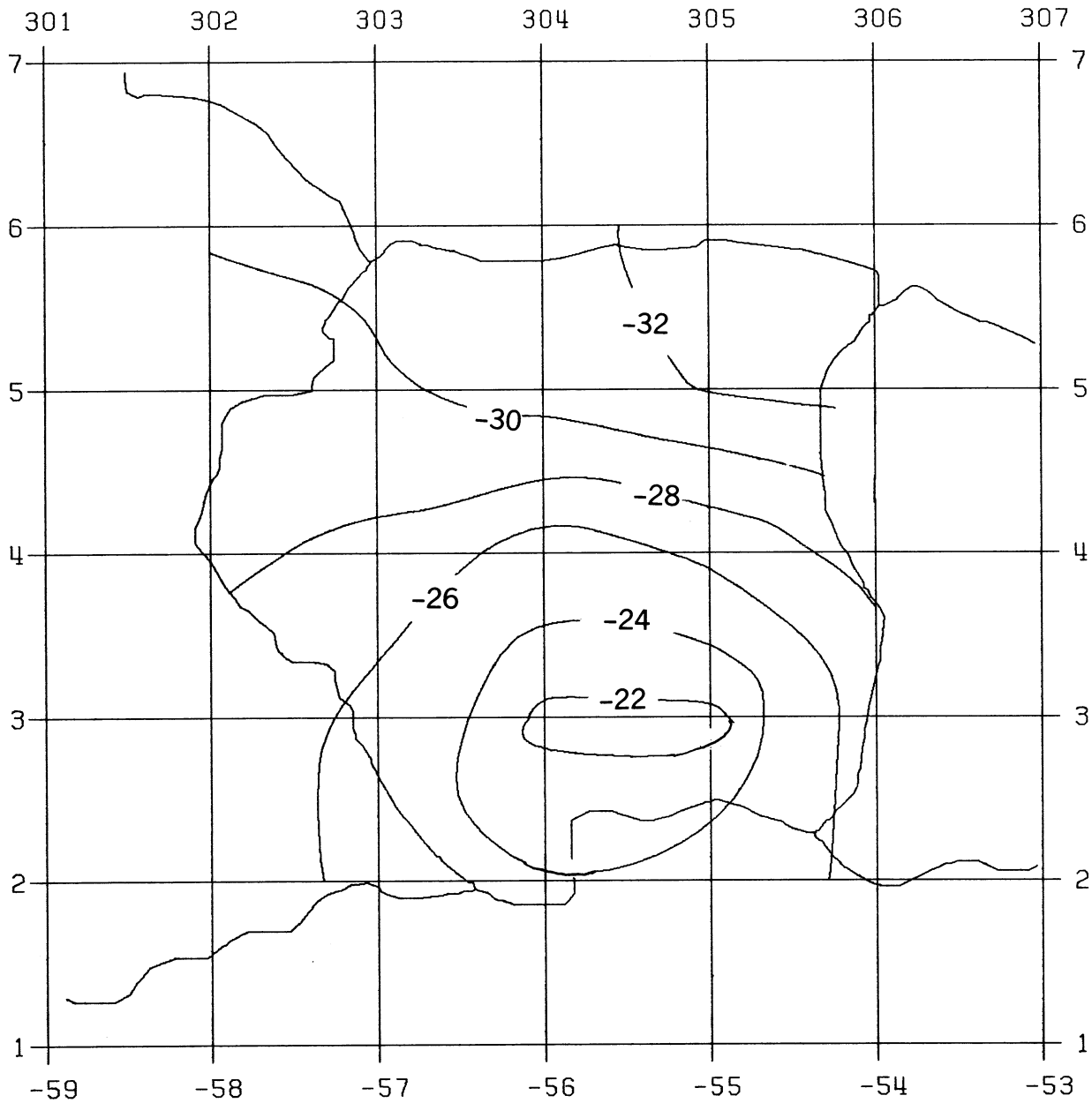

Figure 16.105. Contour Chart–Geodetic Height Differences, WGS 84 Minus Zanderij Datum (Contour Interval = 2 Meters)

SECTION 17

DMA-DEVELOPED LOCAL GEODETIC SYSTEM

GEOID HEIGHT CONTOUR CHARTS FOR MAJOR DATUMS

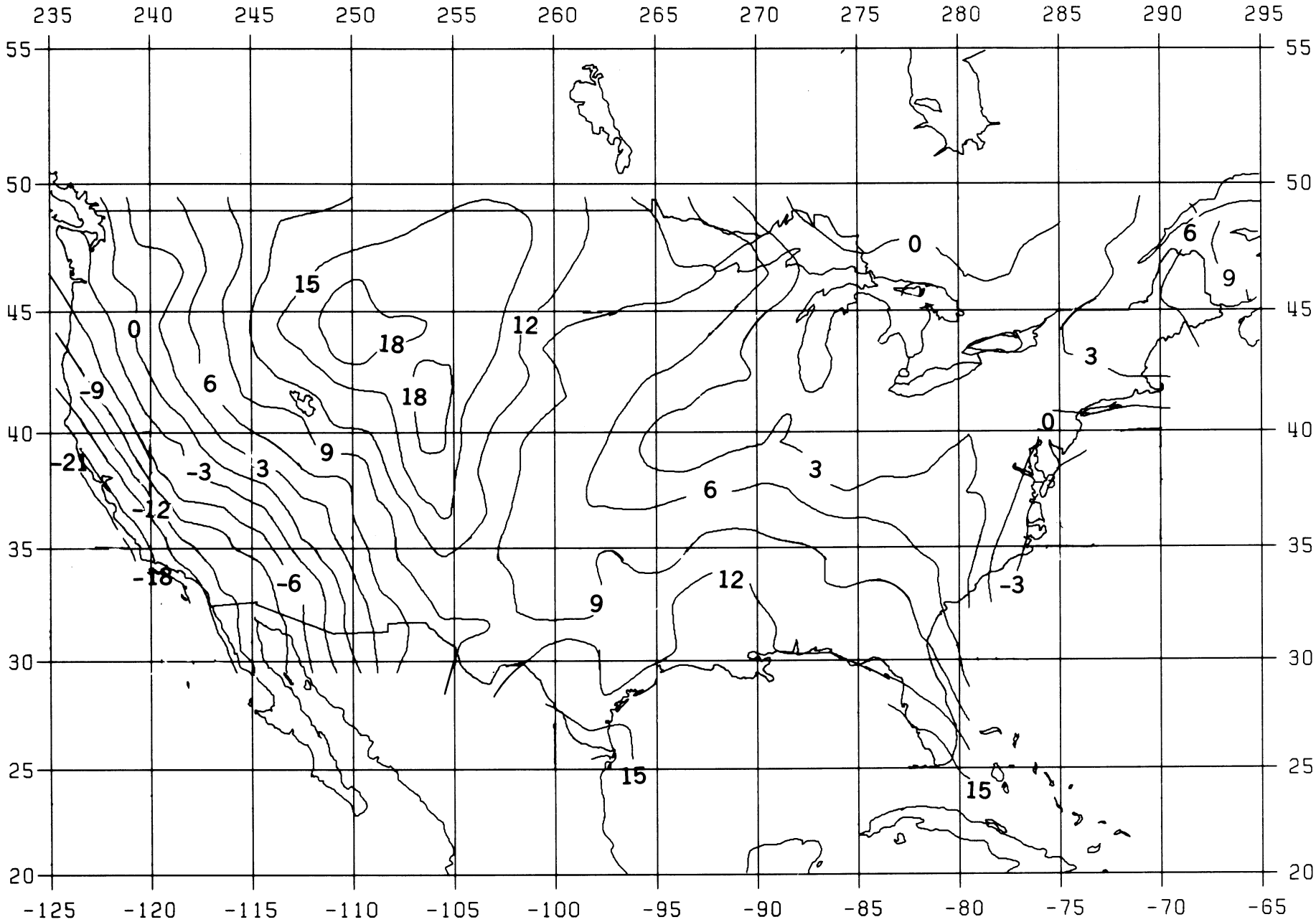

Figure 17.1. DMA-Developed NAD 27 Geoid (CONUS; Referenced to Clarke 1866 Ellipsoid; Units = Meters)

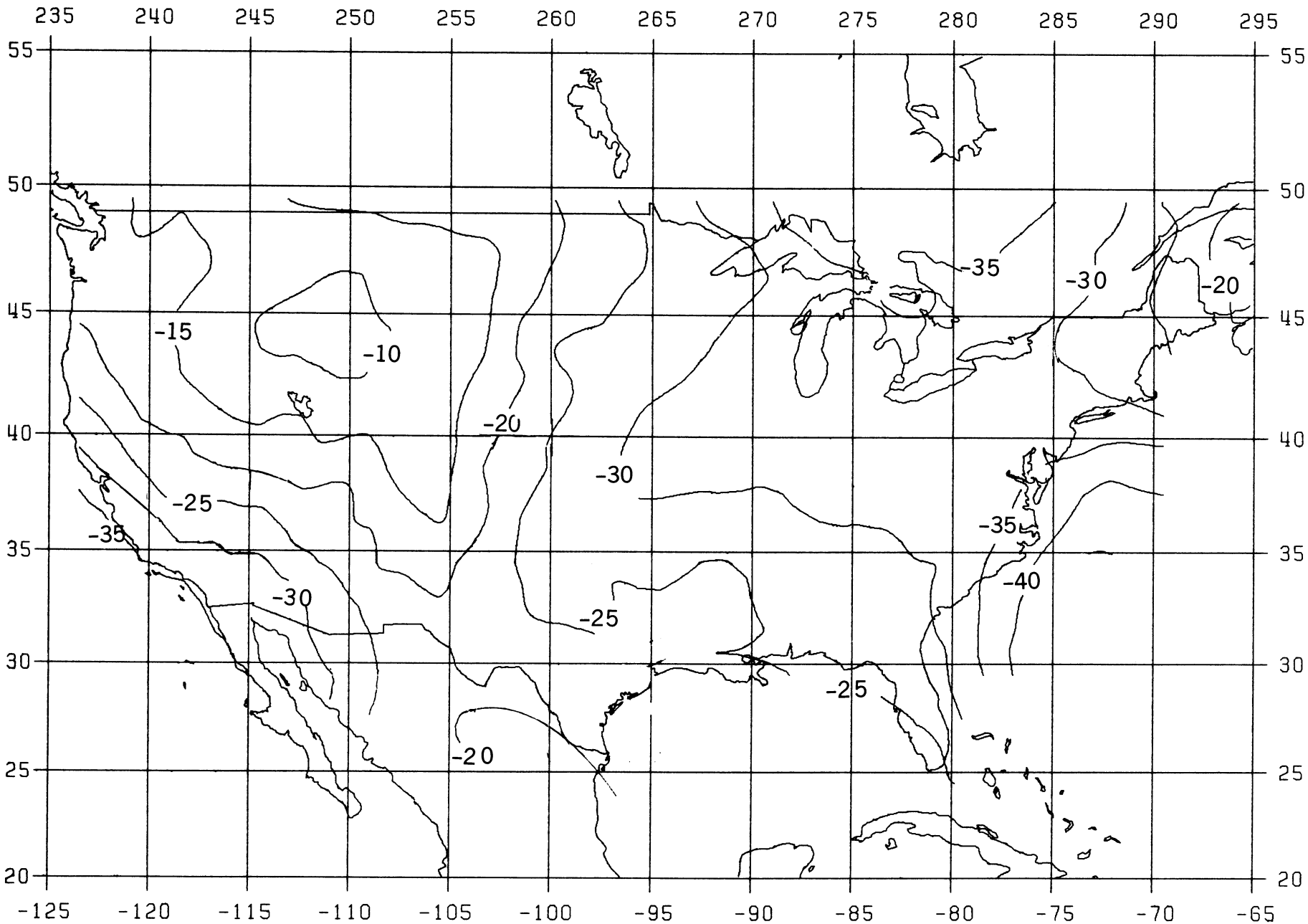

Figure 17.2. DMA-Developed NAD 83 Geoid (CONUS; Referenced to GRS 80 Ellipsoid; Units = Meters)

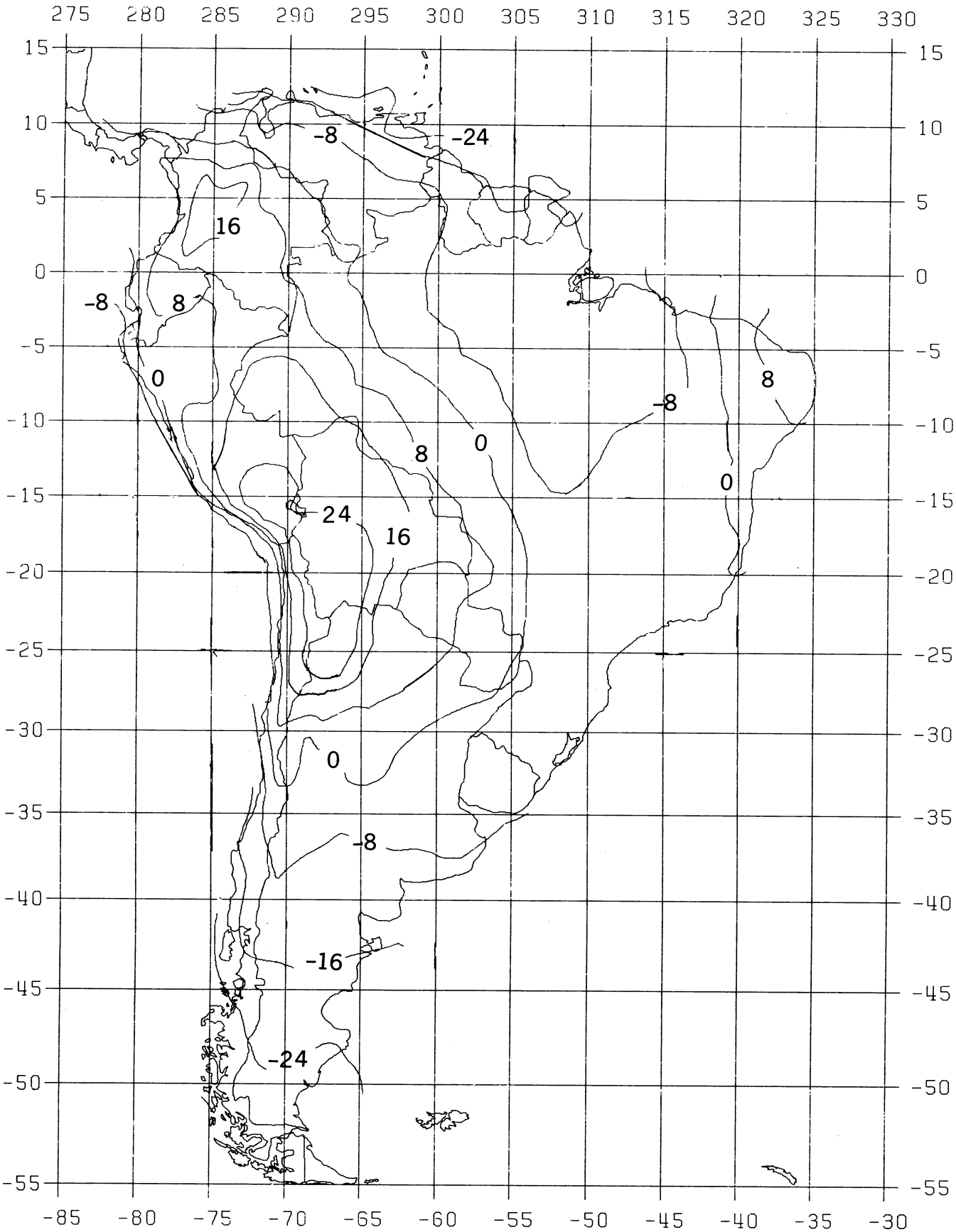

Figure 17.3. DMA-Developed SAD 69 Geoid (Referenced to South American 1969 Ellipsoid; Units = Meters)

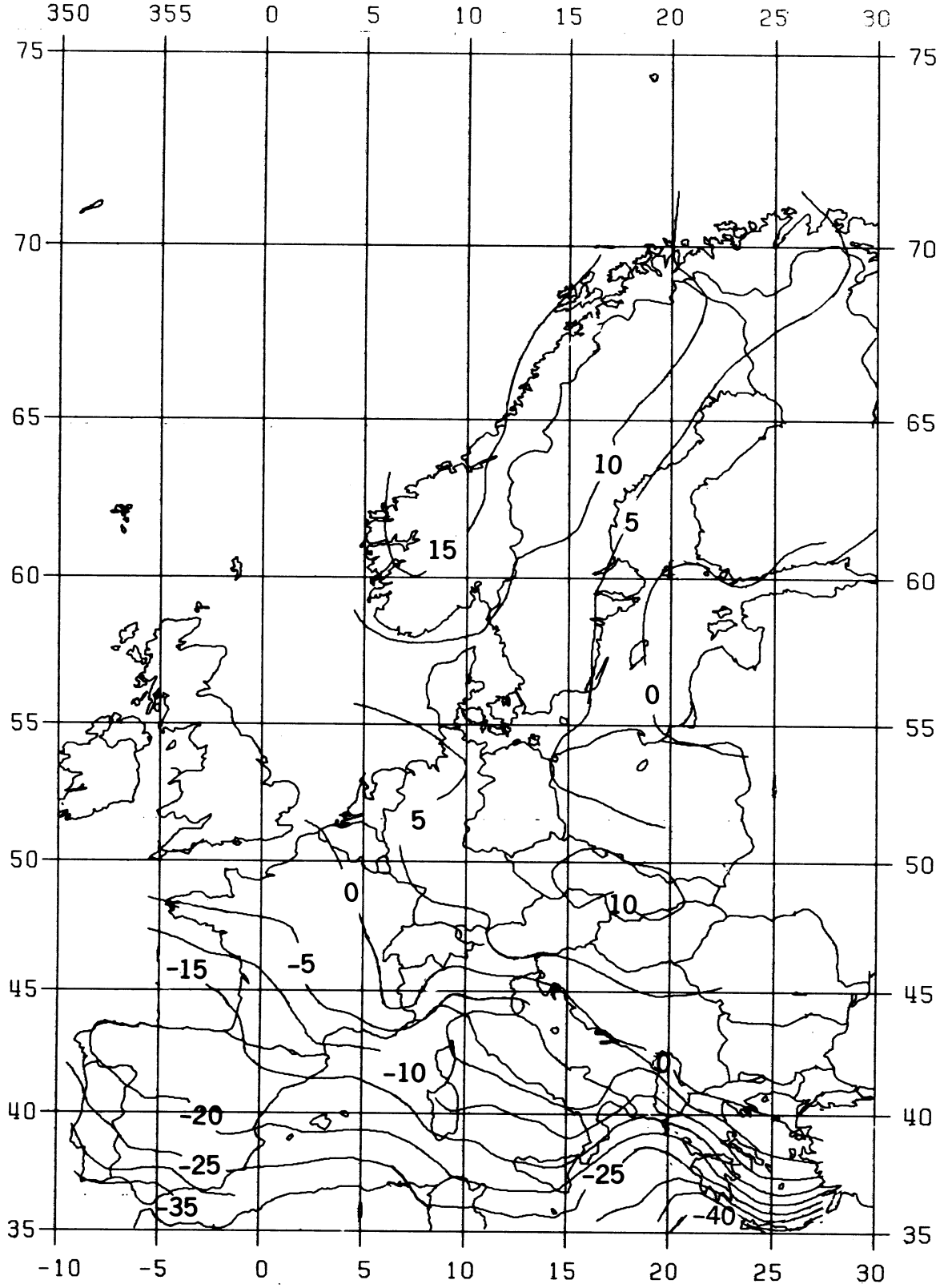

Figure 17.4. **DMA-Developed ED 50 Geoid (Western Europe; Referenced to International Ellipsoid; Units = Meters)**

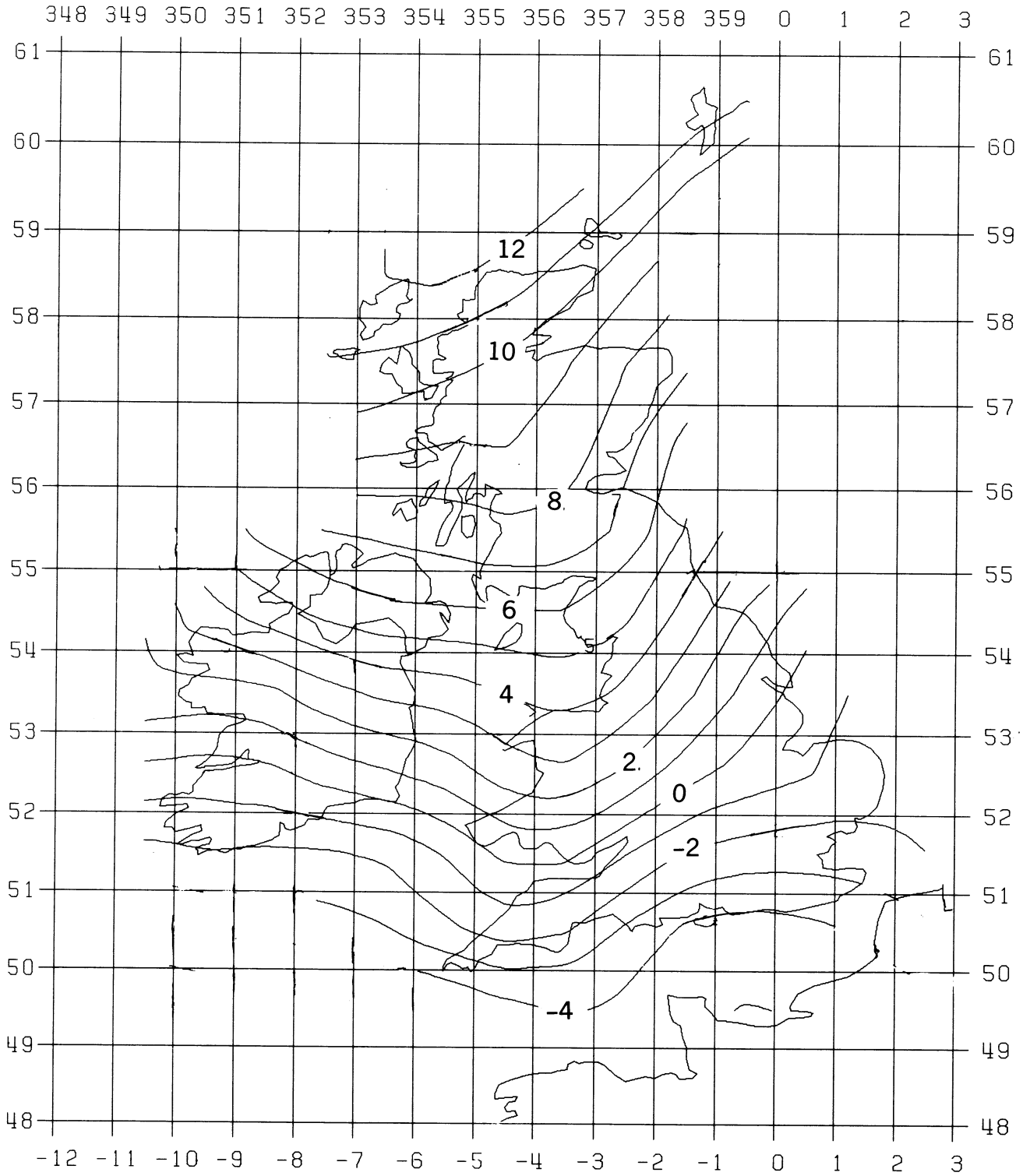

Figure 17.5. DMA-Developed ED 50 Geoid (UK/Ireland; Referenced to International Ellipsoid; Units = Meters)

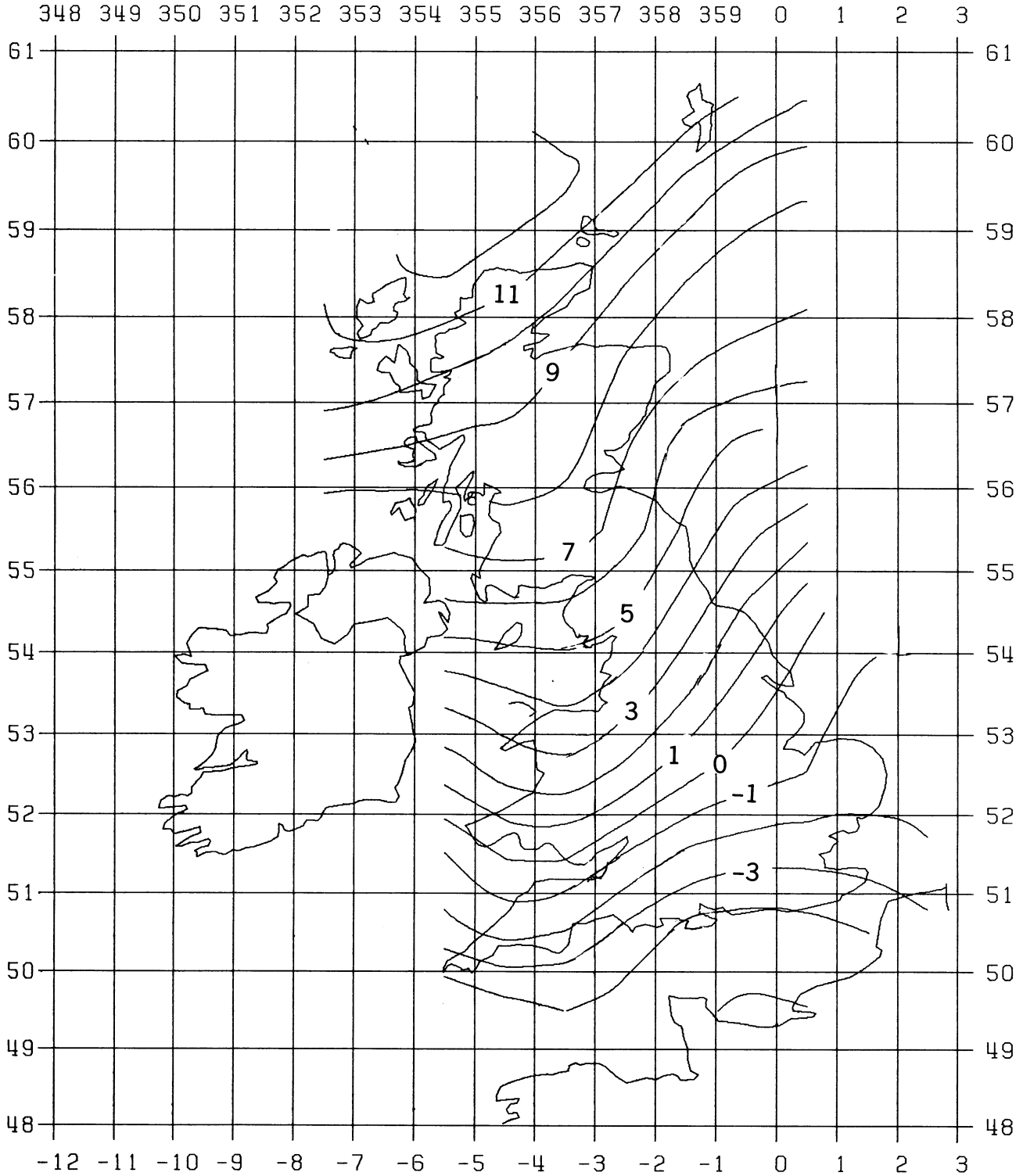

Figure 17.6. DMA-Developed ED 50 Geoid (UK Only; Referenced to International Ellipsoid; Units = Meters)

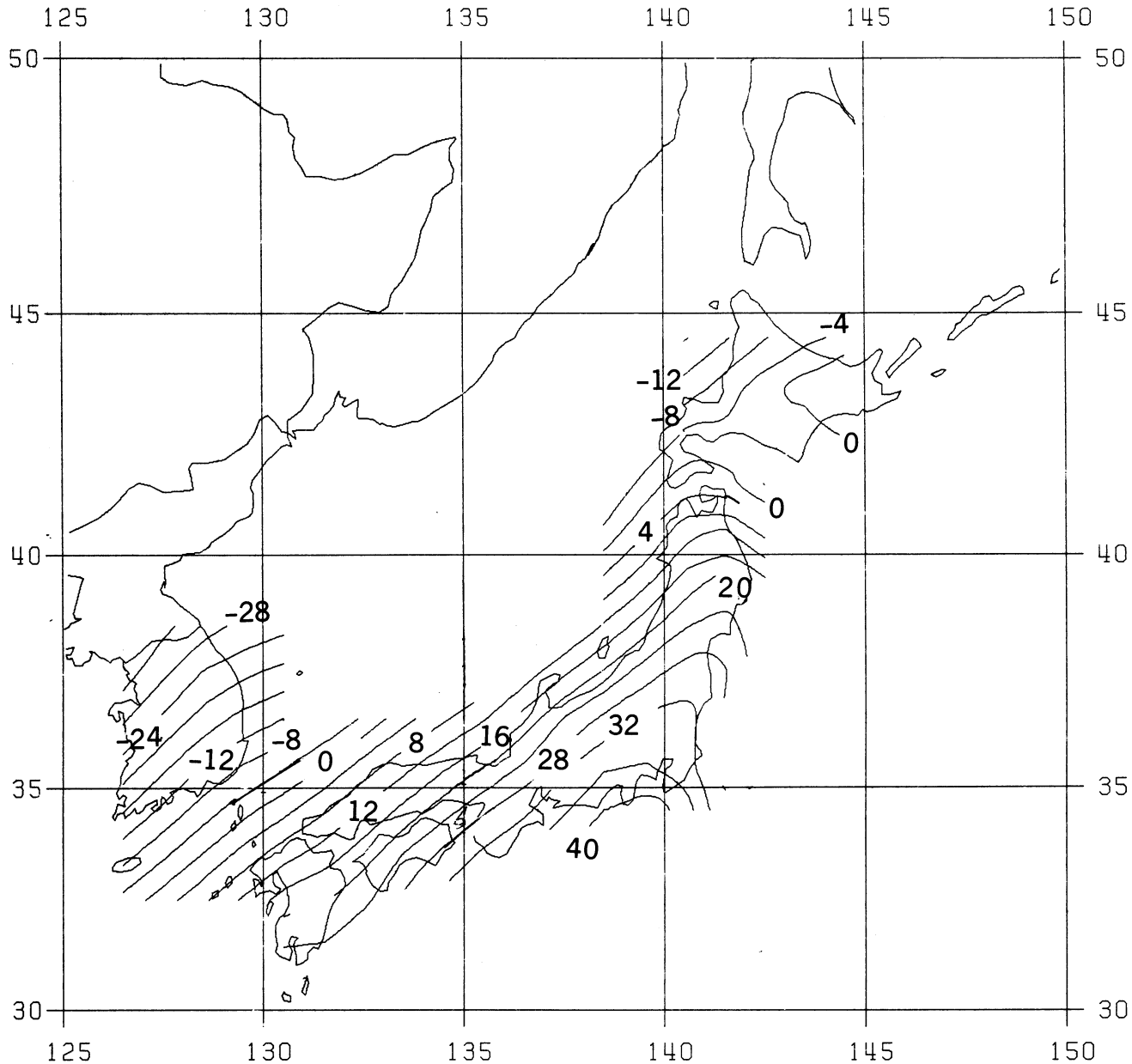

Figure 17.7. DMA-Developed TD Geoid (Referenced to Bessel 1841 Ellipsoid; Units = Meters)

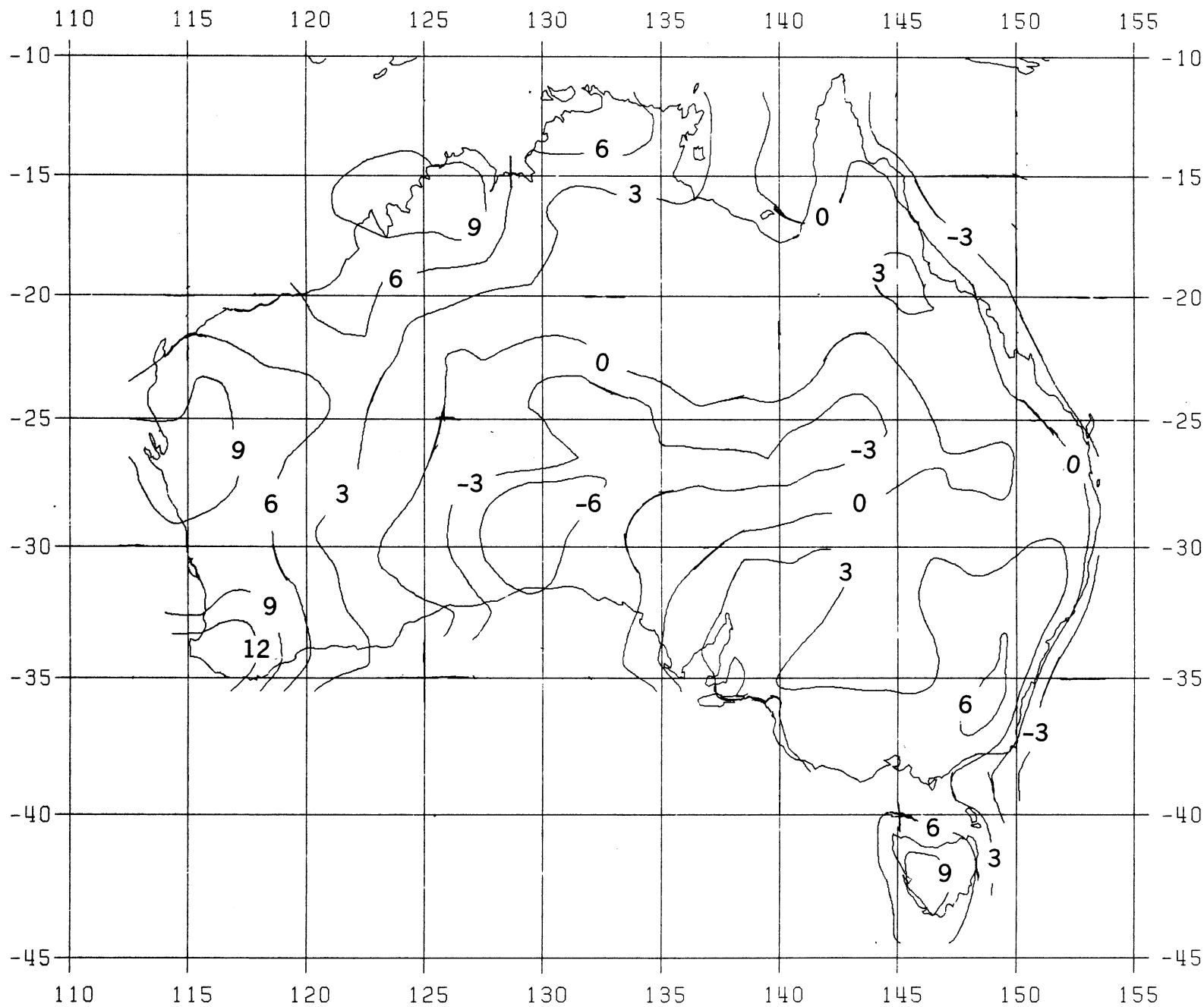

Figure 17.8. DMA-Developed AGD 66 Geoid (Referenced to Australian National Ellipsoid; Units = Meters)

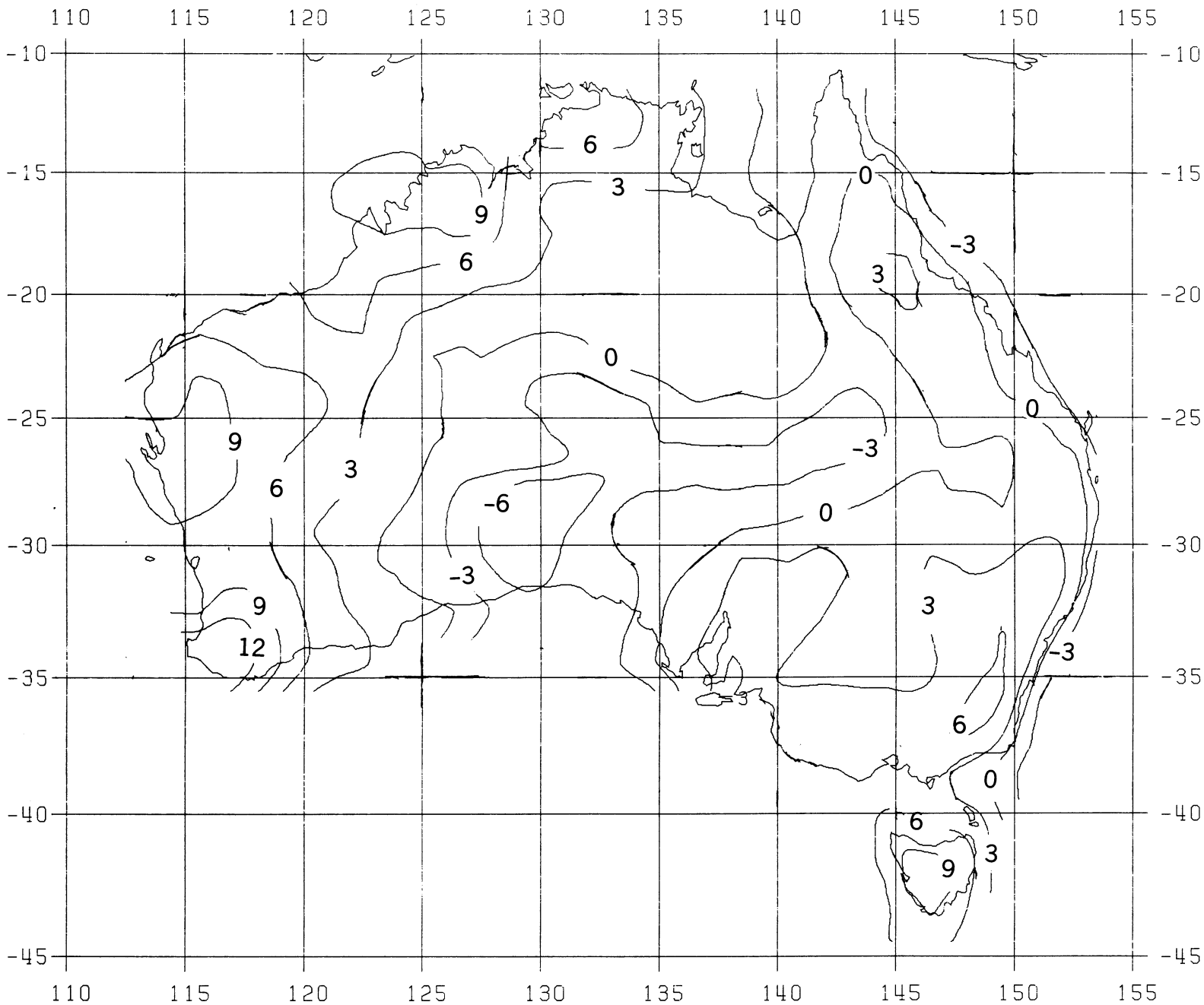

Figure 17.9. DMA-Developed AGD 84 Geoid (Referenced to Australian National Ellipsoid; Units = Meters)

SECTION 18

[Revised: 30 September 1988]

DMA-DEVELOPED LOCAL GEODETIC SYSTEM GEOID HEIGHT CONTOUR CHARTS FOR AN ADDITIONAL 30 OF THE 83 LOCAL GEODETIC SYSTEMS* -

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* CONTOUR CHARTS NOT INCLUDED FOR EUROPEAN DATUM 1979 (SINCE IT DOES NOT REPLACE ED 50), OR FOR THOSE LOCAL GEODETIC SYSTEMS WHERE THE USE OF GEOID HEIGHT CONTOUR CHARTS WOULD HAVE LITTLE OR NO PRACTICAL VALUE (MOST ISLAND DATUMS AND/OR DATUMS REPRESENTING SMALL GEOGRAPHICAL AREAS). FOR DMA-DEVELOPED GEOID HEIGHTS FOR SUCH LOCAL GEODETIC SYSTEMS, SEE SECTION 23 (IN PARTICULAR, TABLE 23.43).

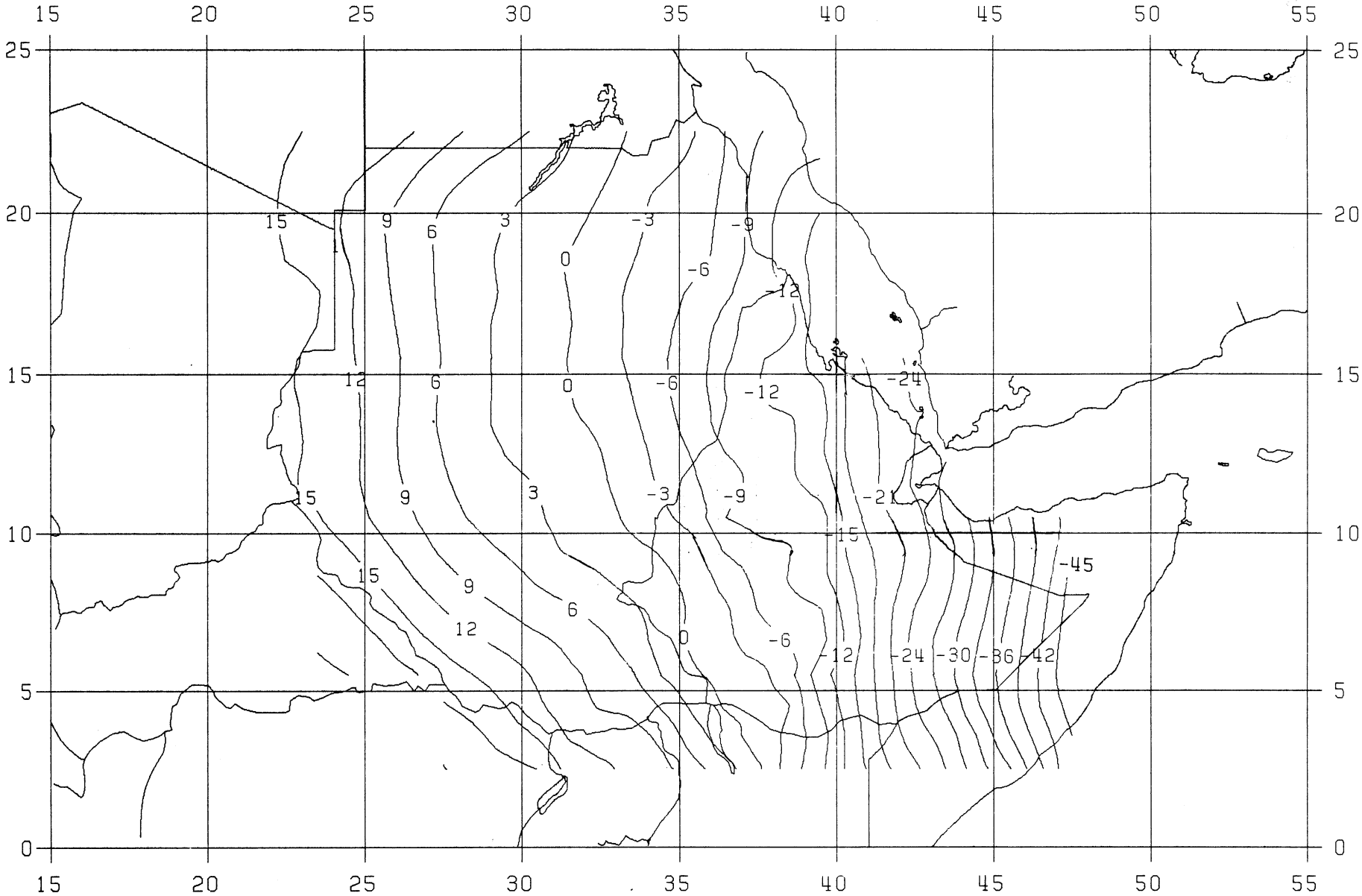

Figure 18.1. DMA-Developed Adindan Datum Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

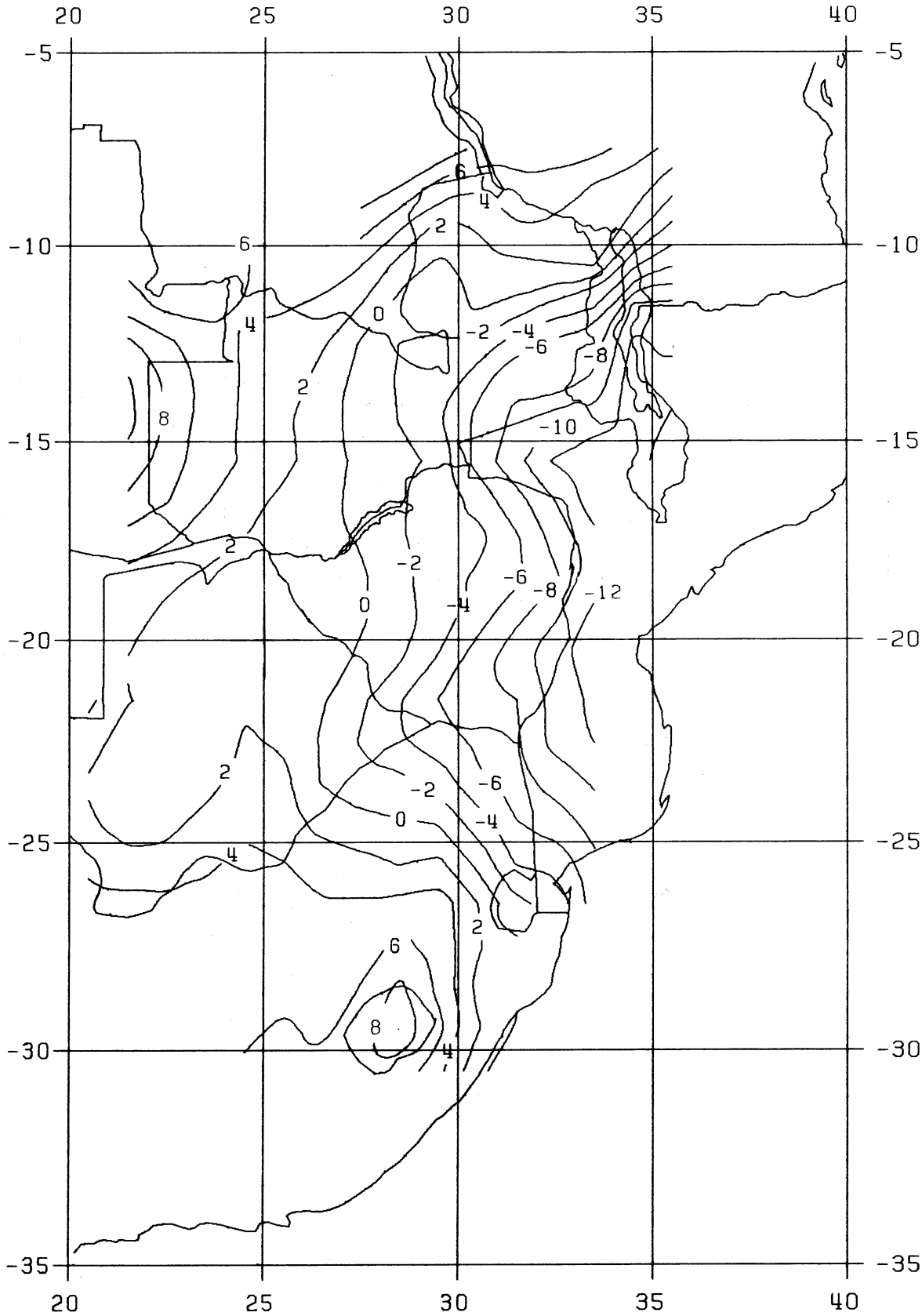

Figure 18.2. DMA-Developed Arc Datum 1950 Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

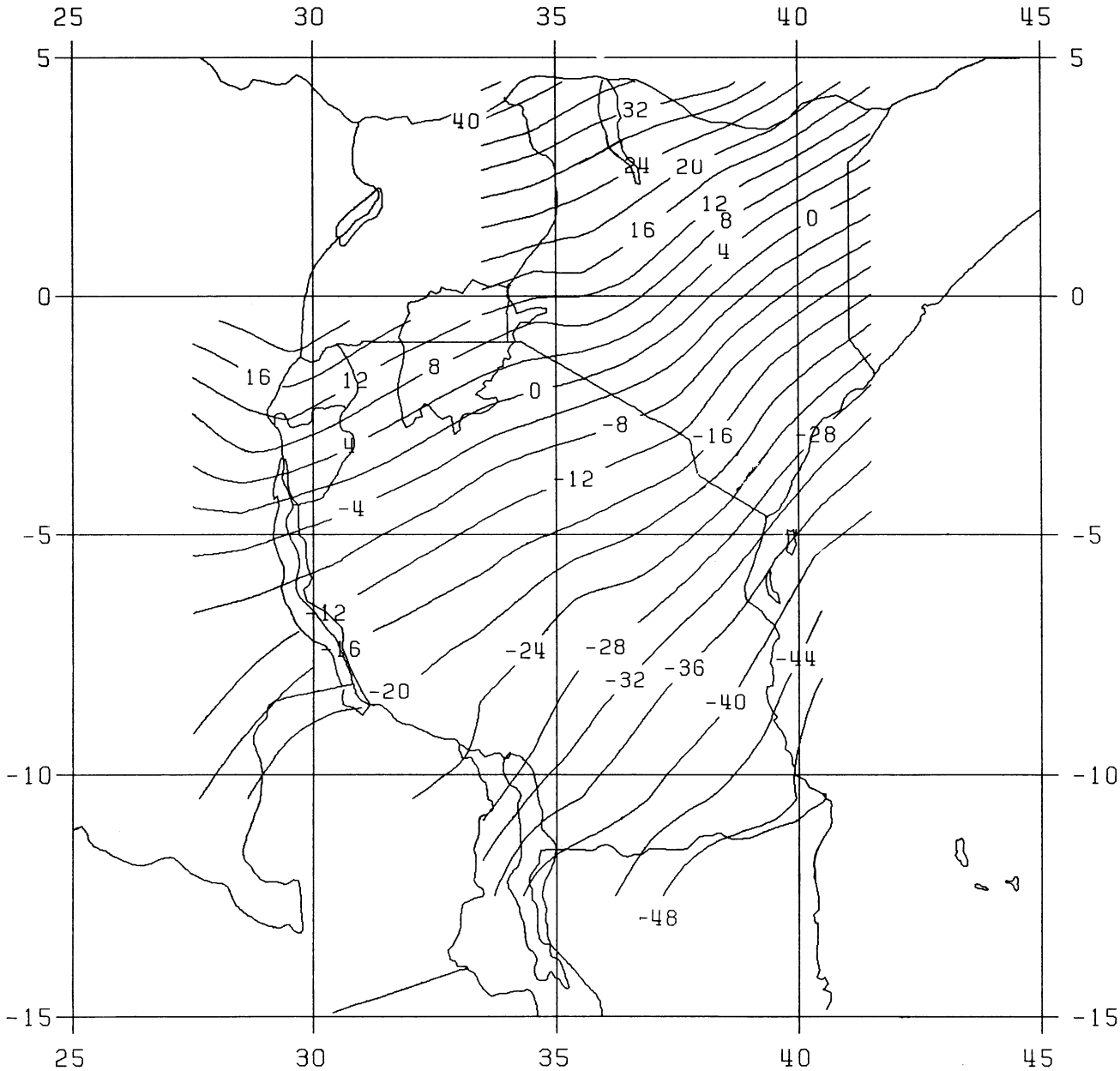

Figure 18.3. DMA- Developed Arc Datum 1960 Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

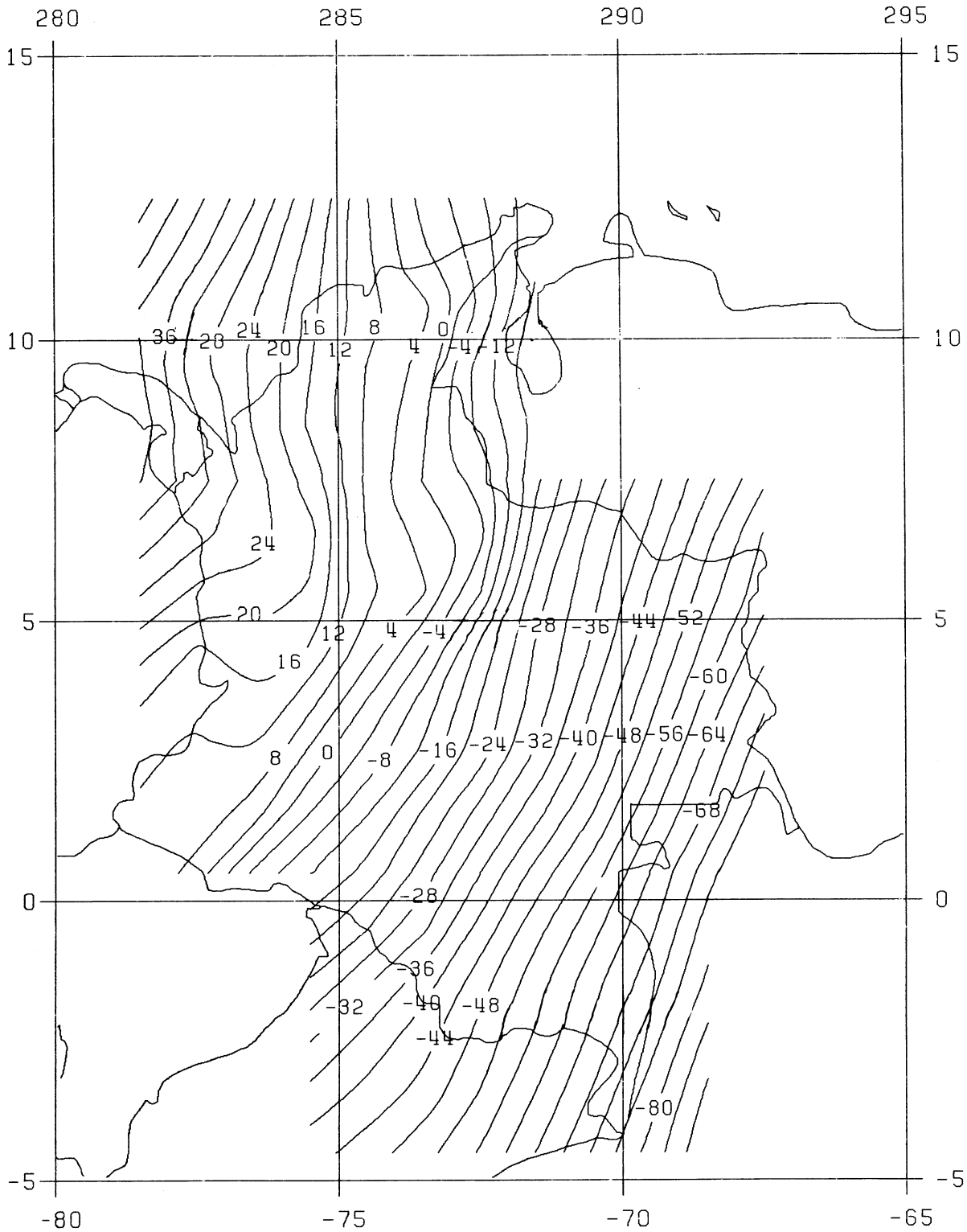

Figure 18.4. DMA-Developed Bogota Observatory Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

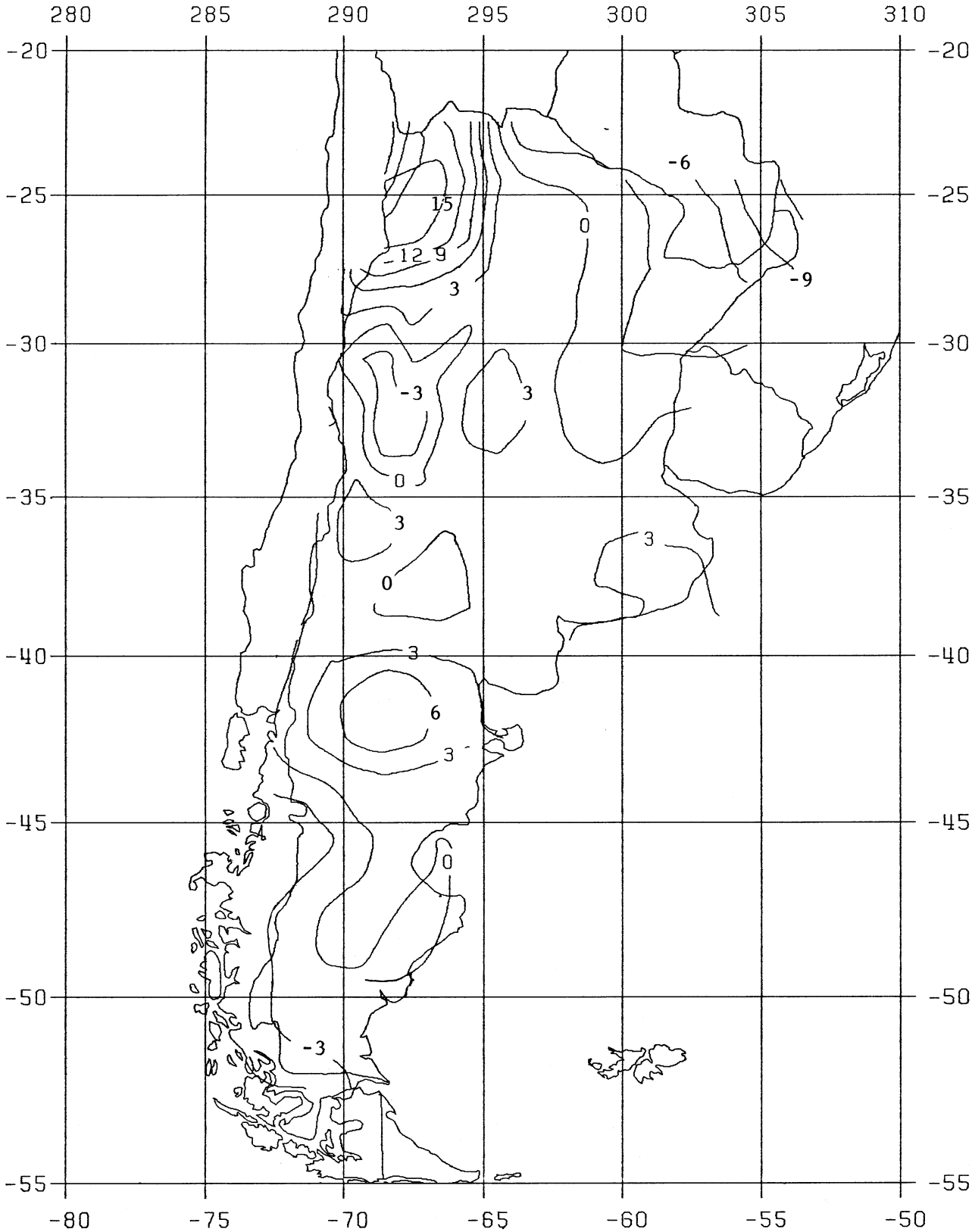

Figure 18.5. DMA-Developed Campo Inchauspe Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

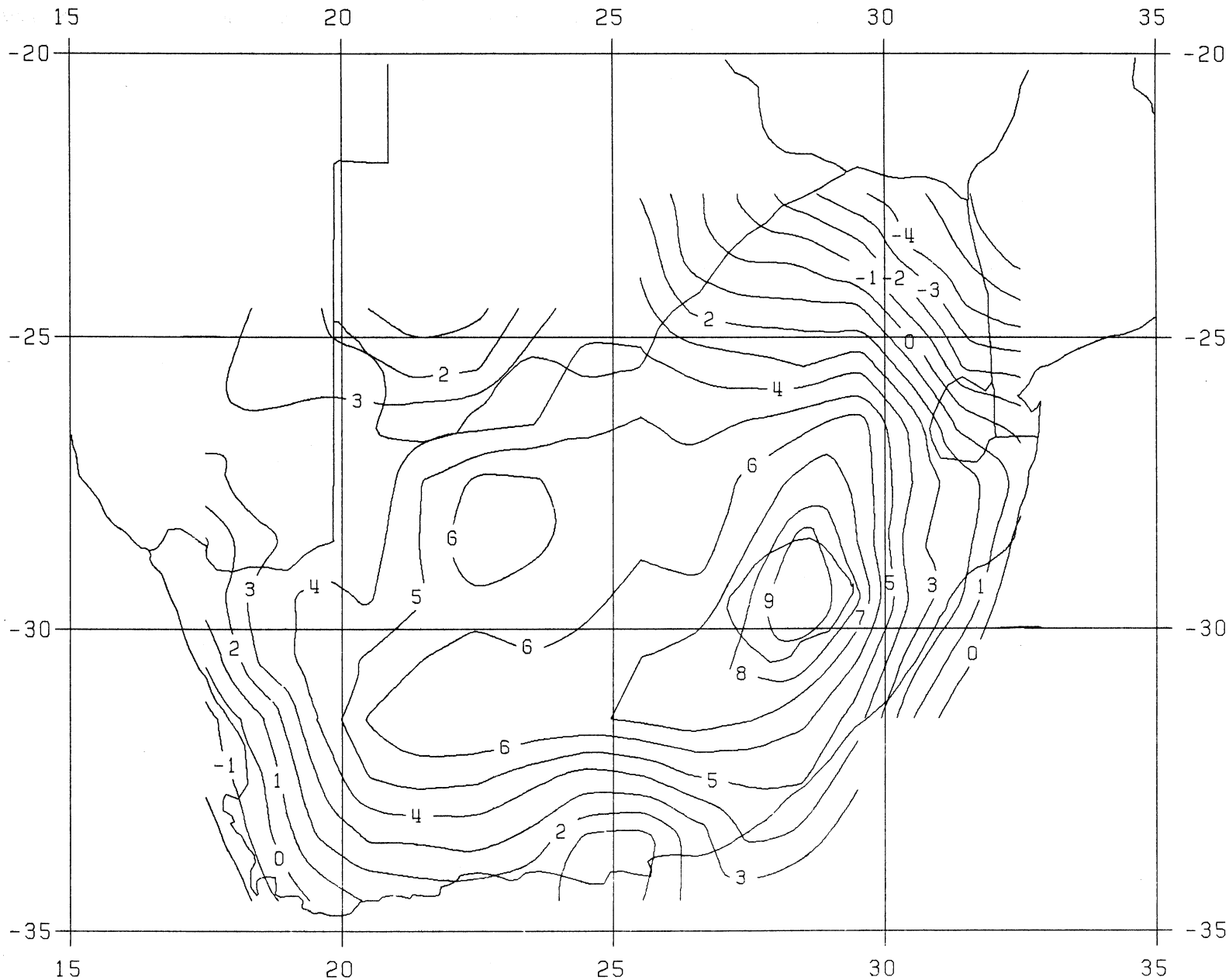

Figure 18.6. DMA-Developed Cape Datum Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

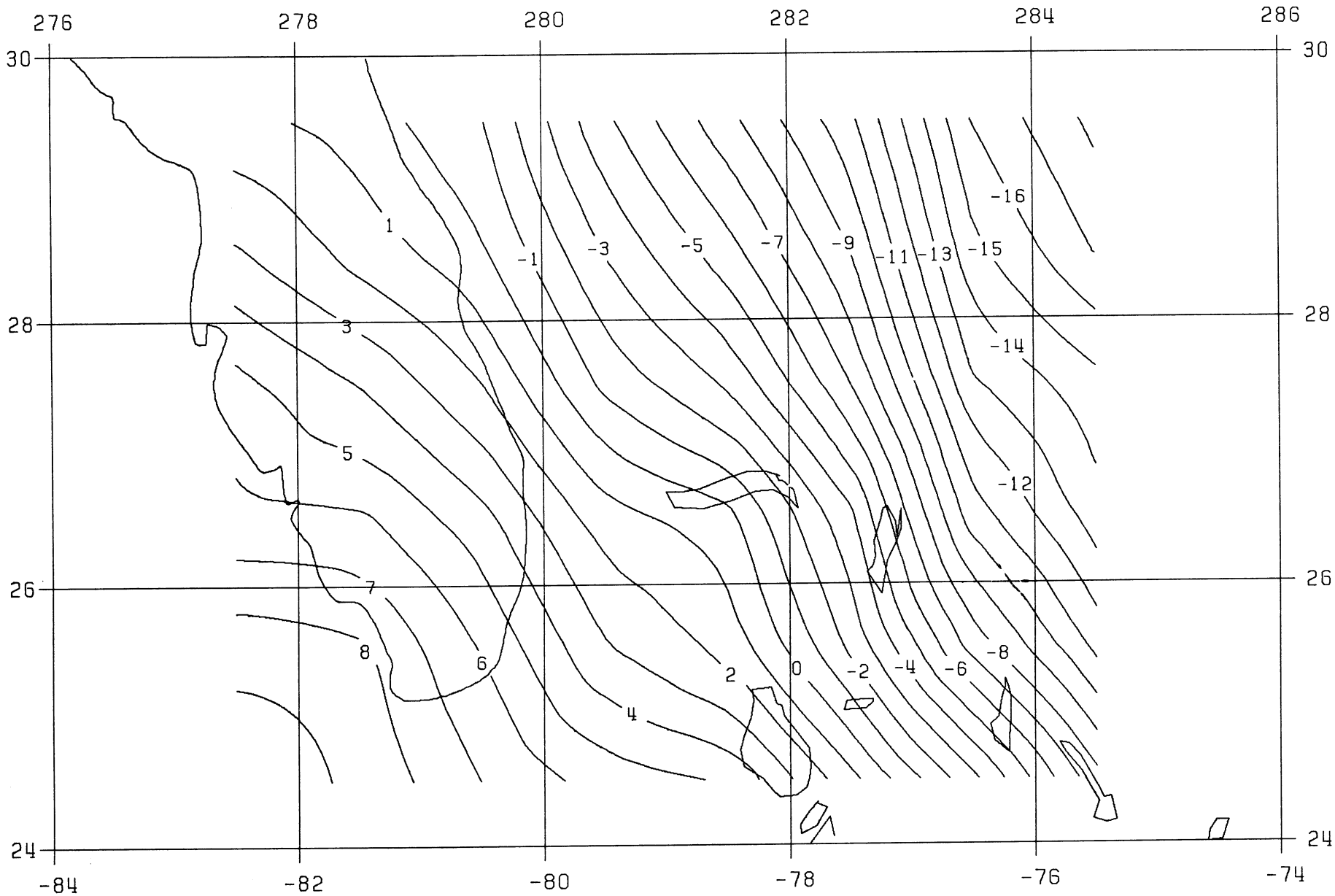

Figure 18.7. DMA-Developed Cape Canaveral Datum Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

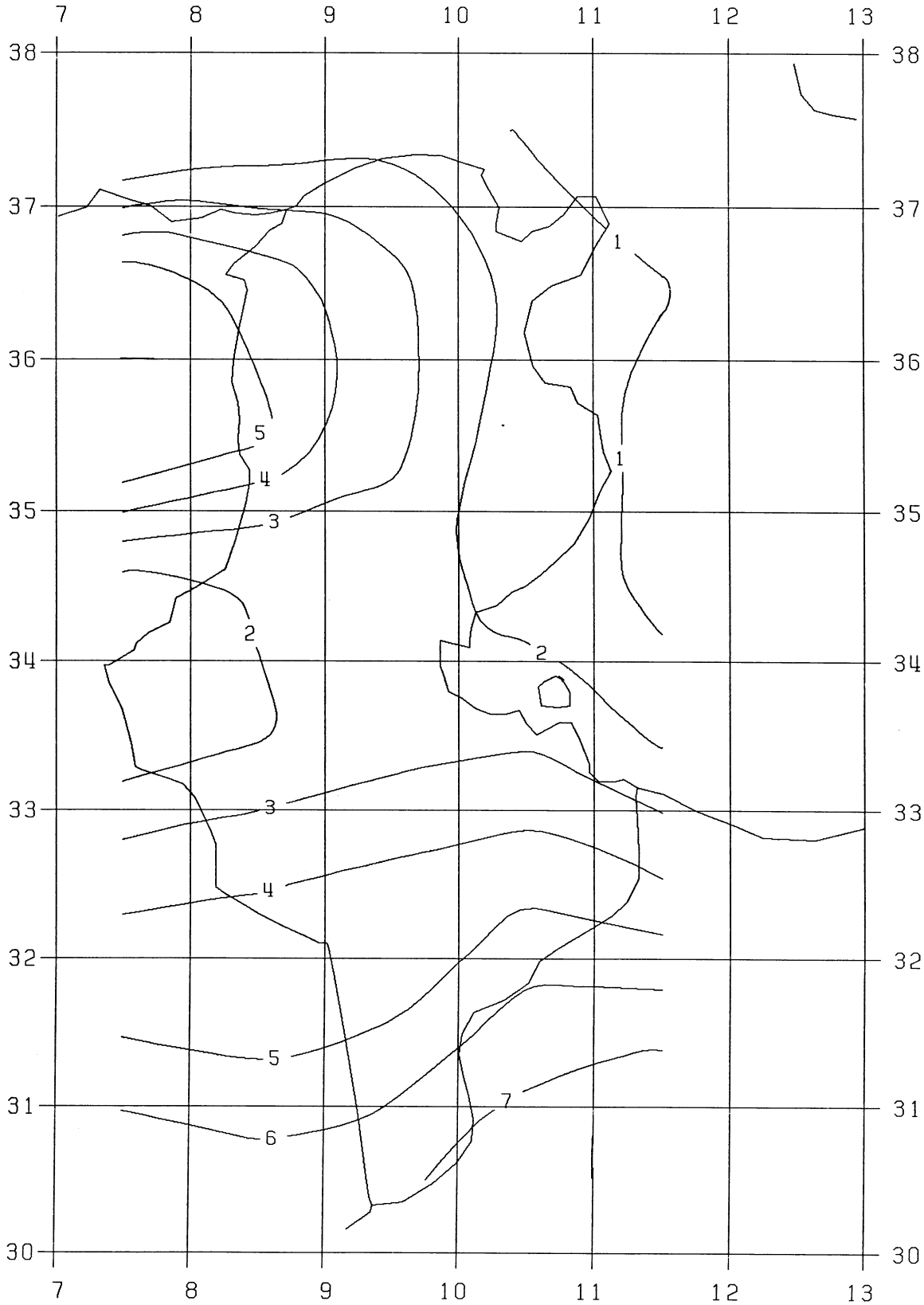

Figure 18.8. DMA-Developed Carthage Datum Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

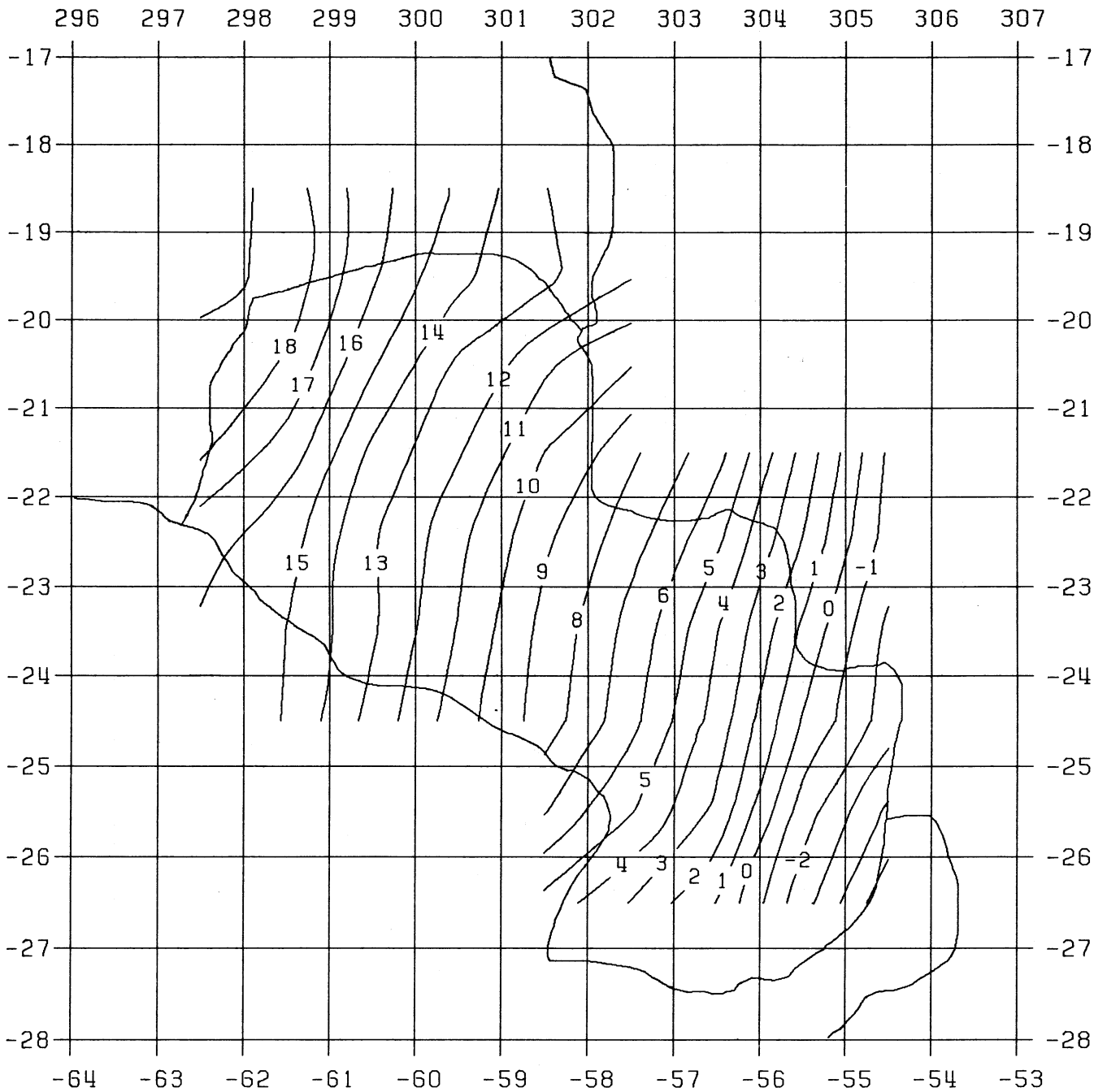

Figure 18.9. DMA-Developed Chua Astro Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

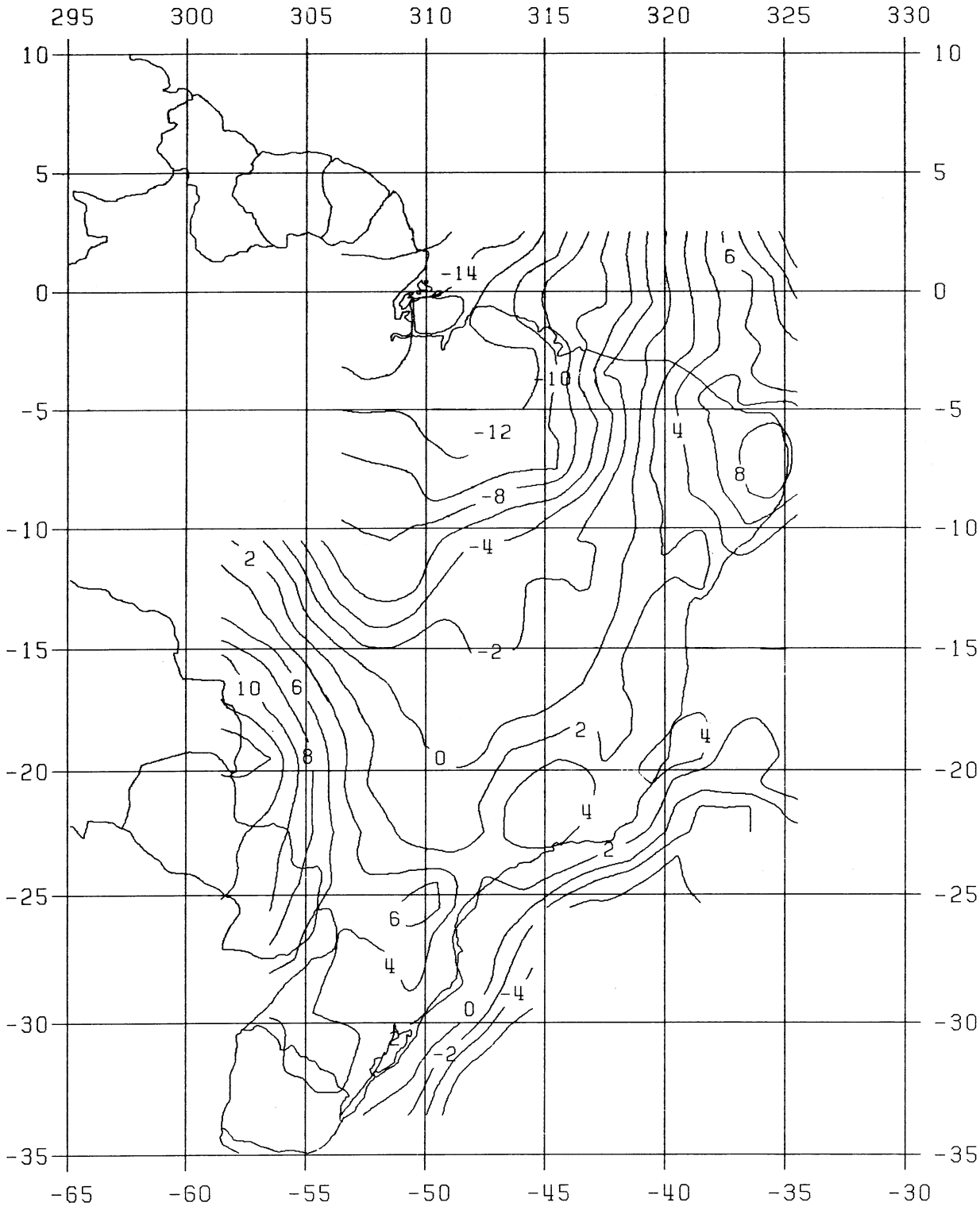

Figure 18.10. DMA-Developed Corrego Alegre Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

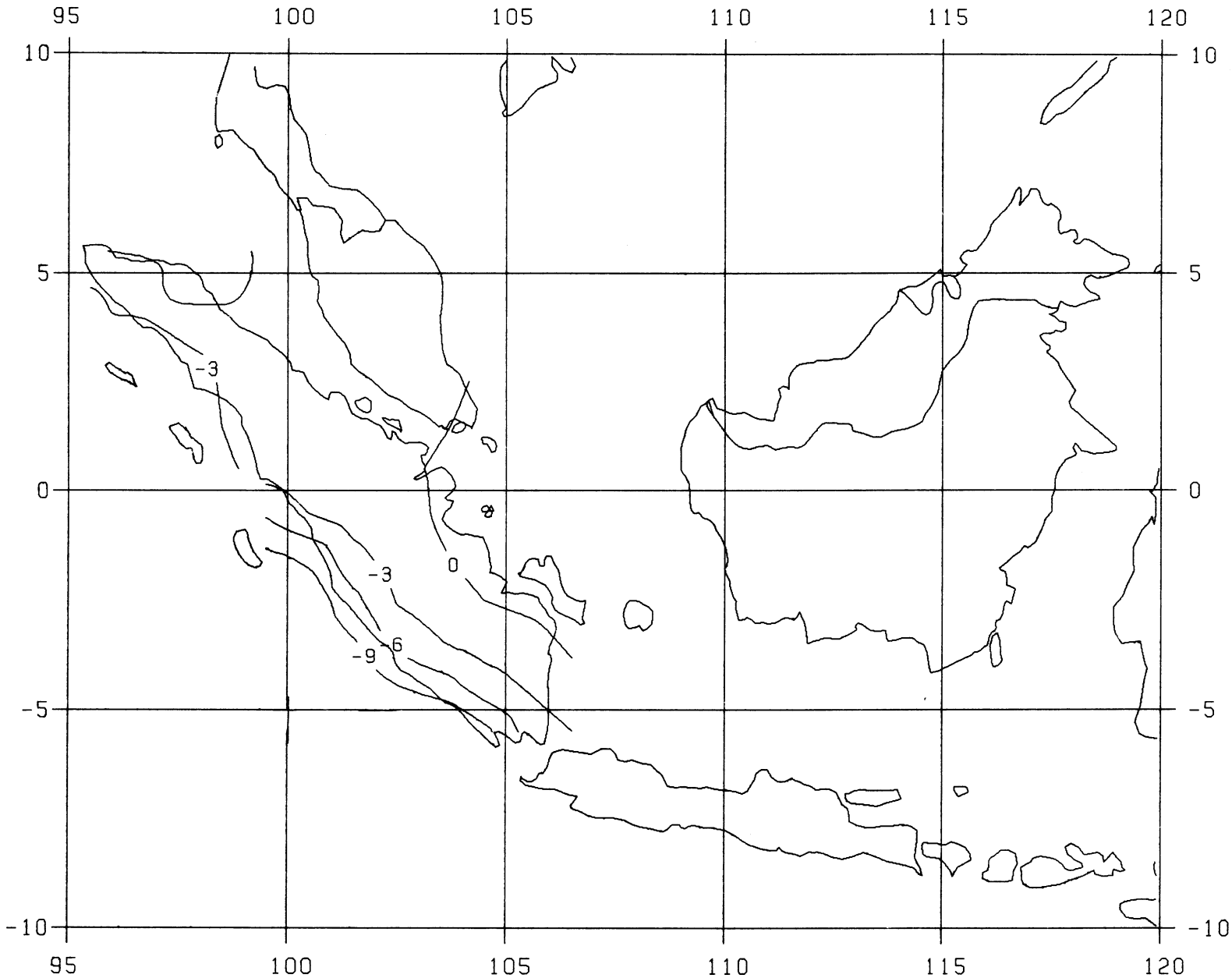

Figure 18.11. DMA-Developed Djakarta Datum Geoid (Referenced to Bessel 1841 Ellipsoid; Units = Meters)

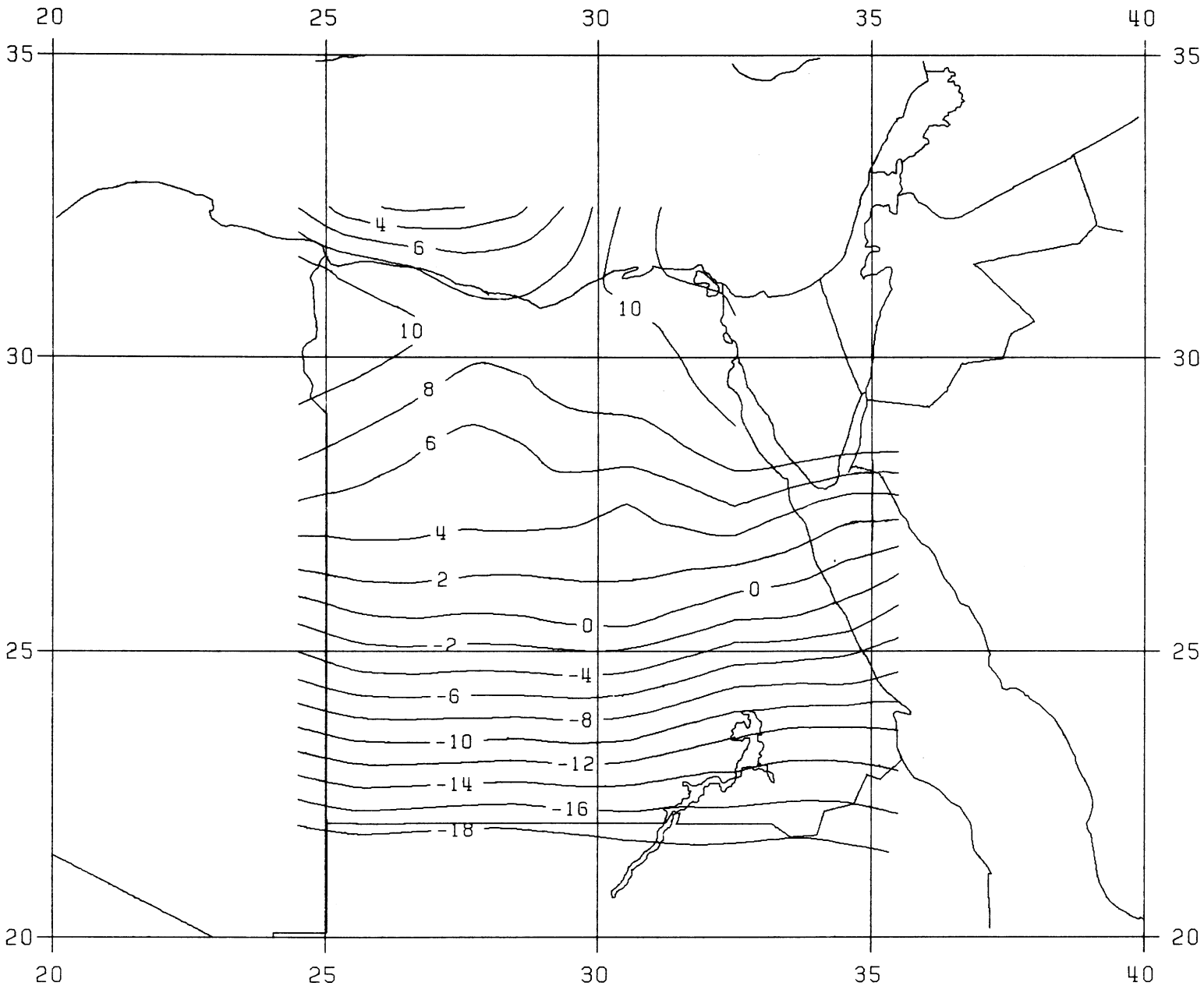

Figure 18.12. DMA-Developed ED 50 (Egypt) Geoid (Referenced to International Ellipsoid; Units = Meters)

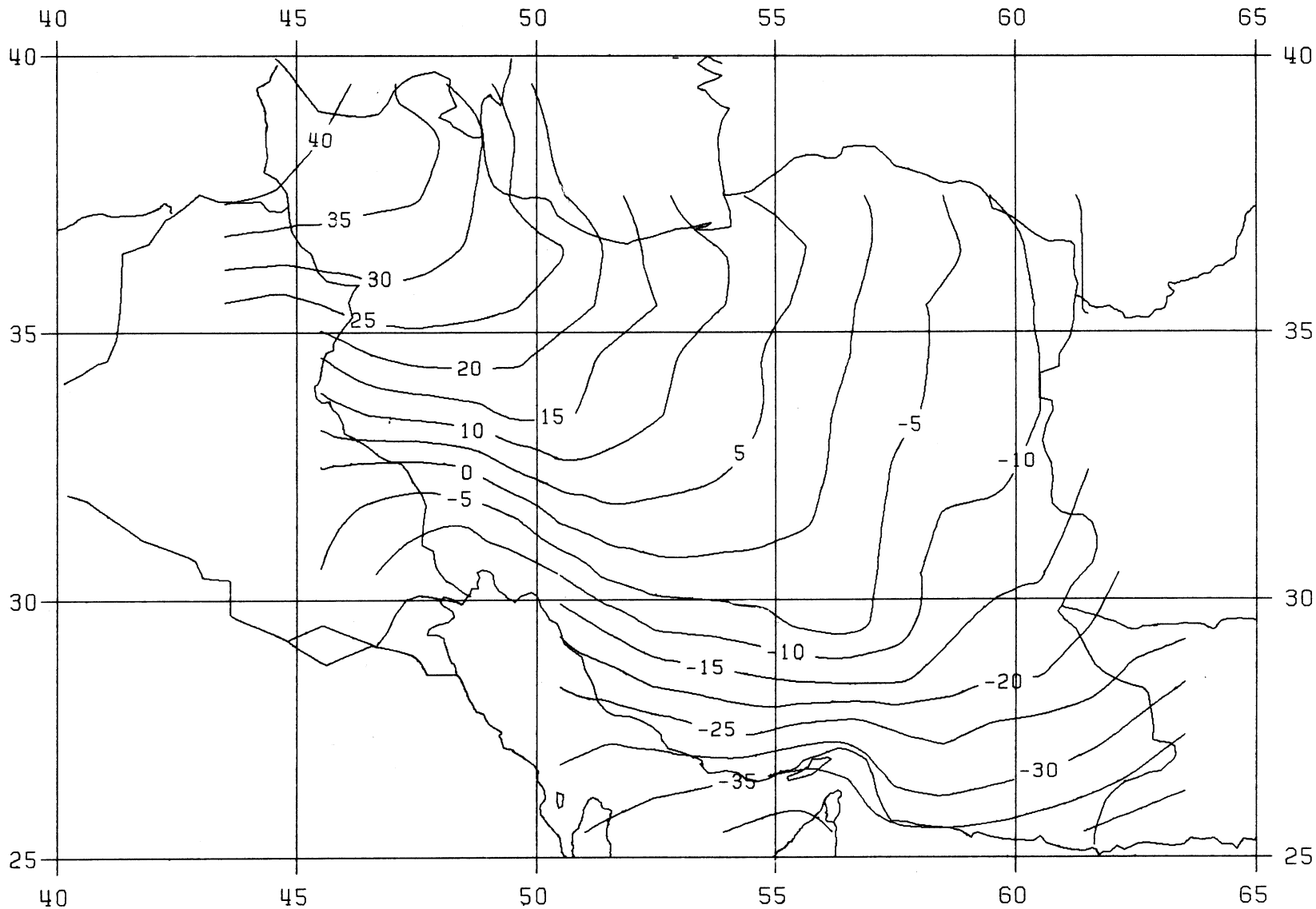

Figure 18.13. DMA-Developed ED 50 (Iran) Geoid (Referenced to International Ellipsoid; Units = Meters)

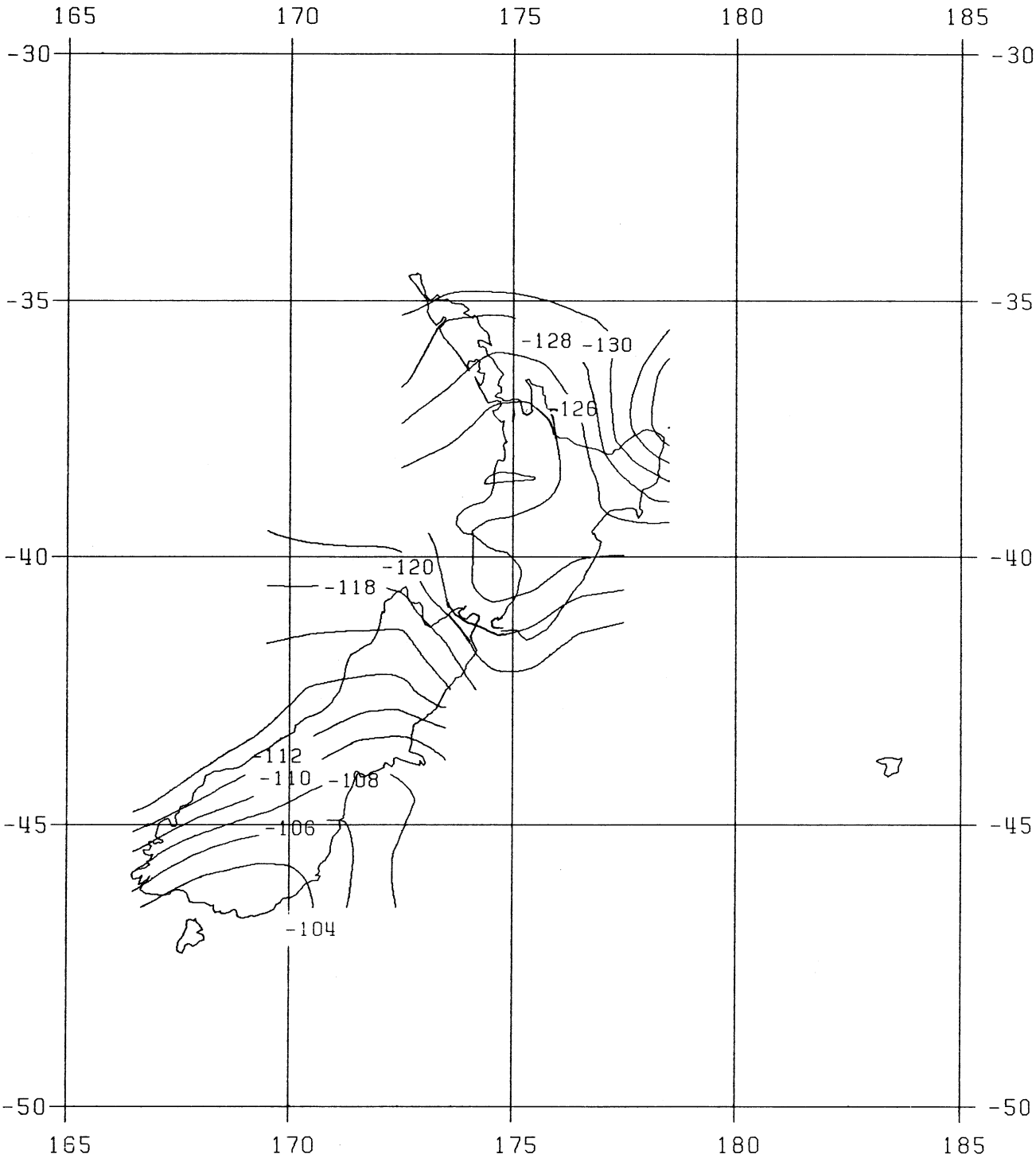

Figure 18.14. DMA-Developed Geodetic Datum 1949 Geoid (Referenced to International Ellipsoid; Units = Meters)

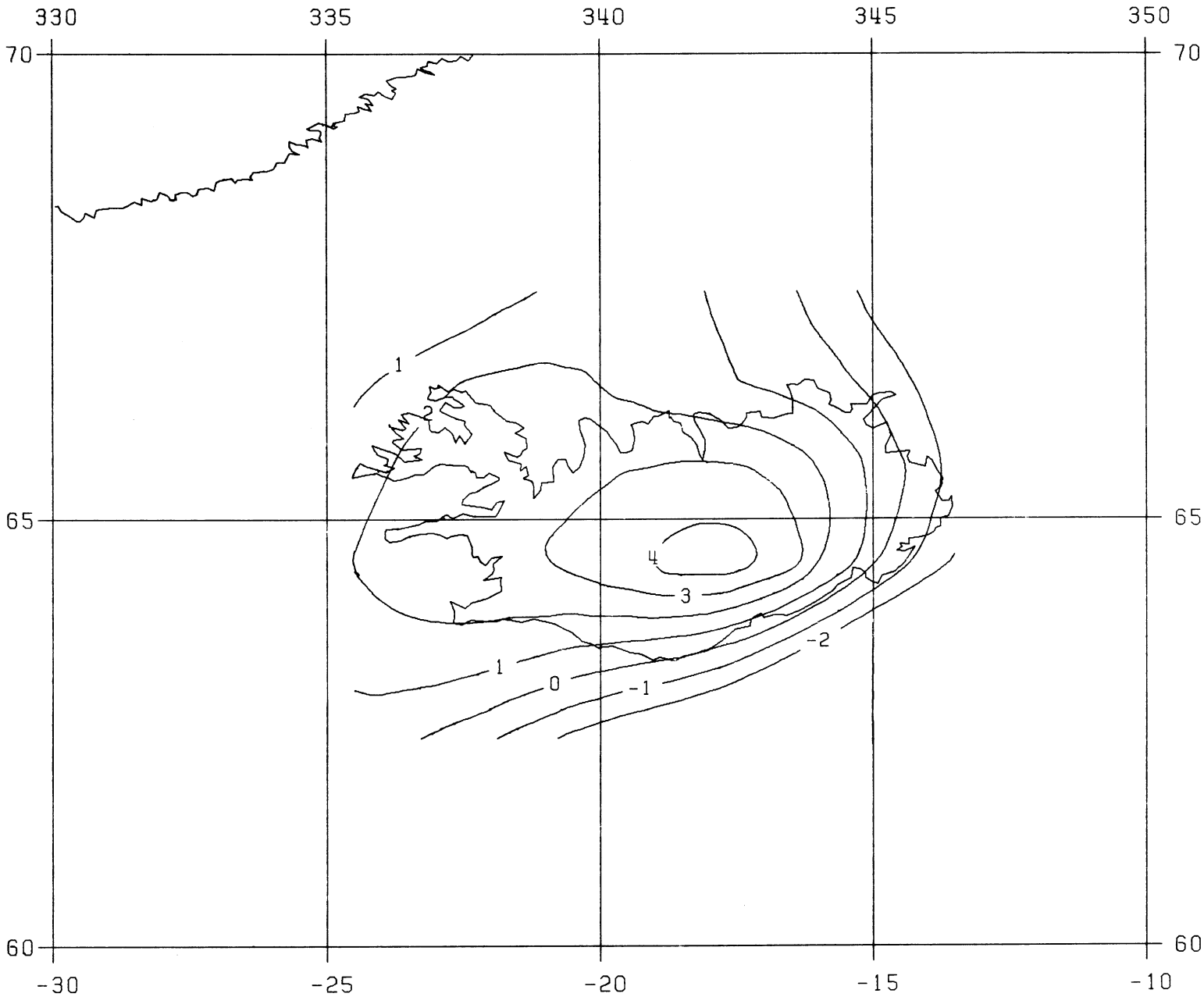

Figure 18.15. DMA-Developed Hjorsey Datum 1955 Geoid (Referenced to International Ellipsoid; Units = Meters)

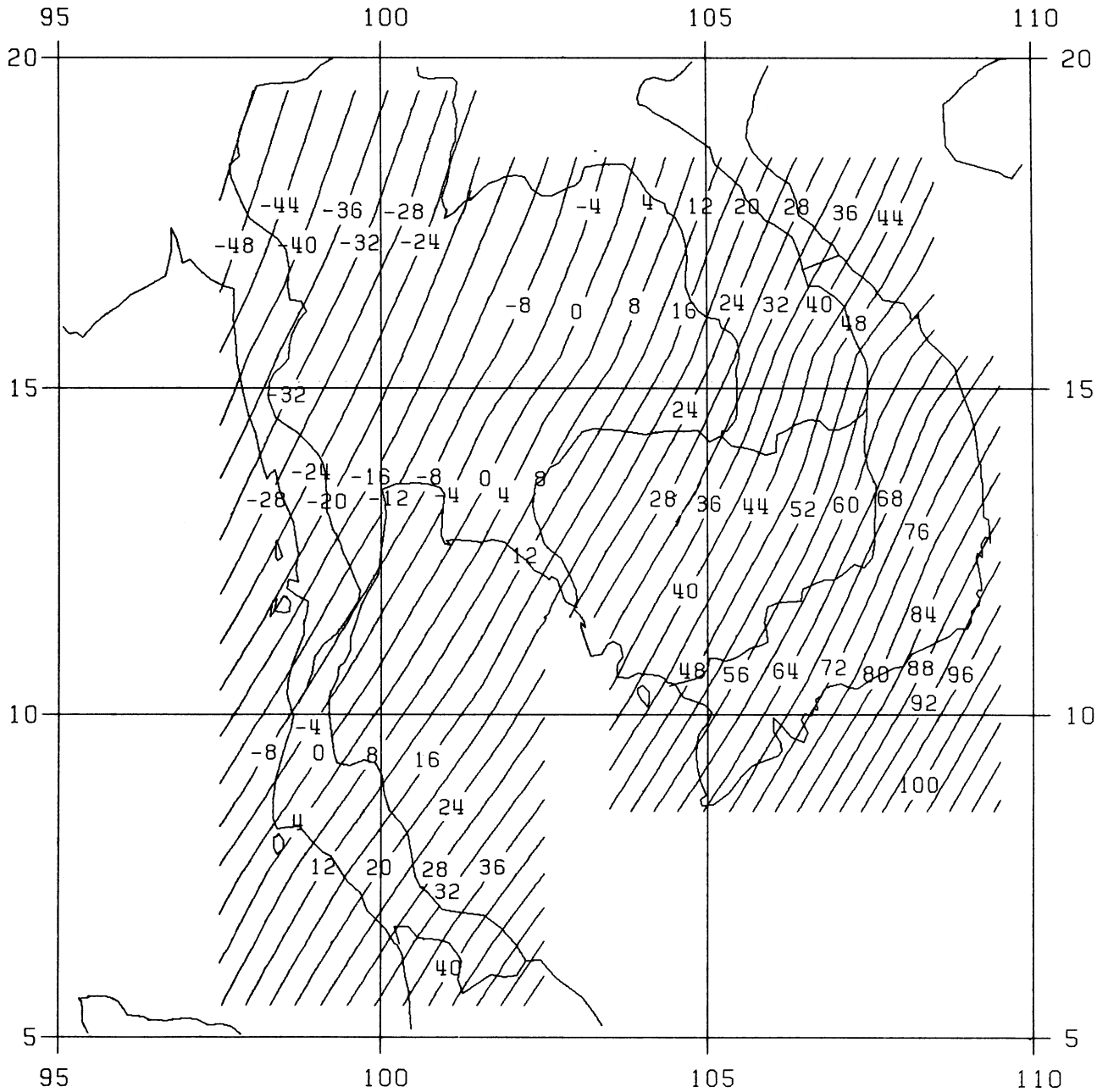

Figure 18.16. DMA-Developed Indian Datum Geoid (Referenced to Everest Ellipsoid; Units = Meters)

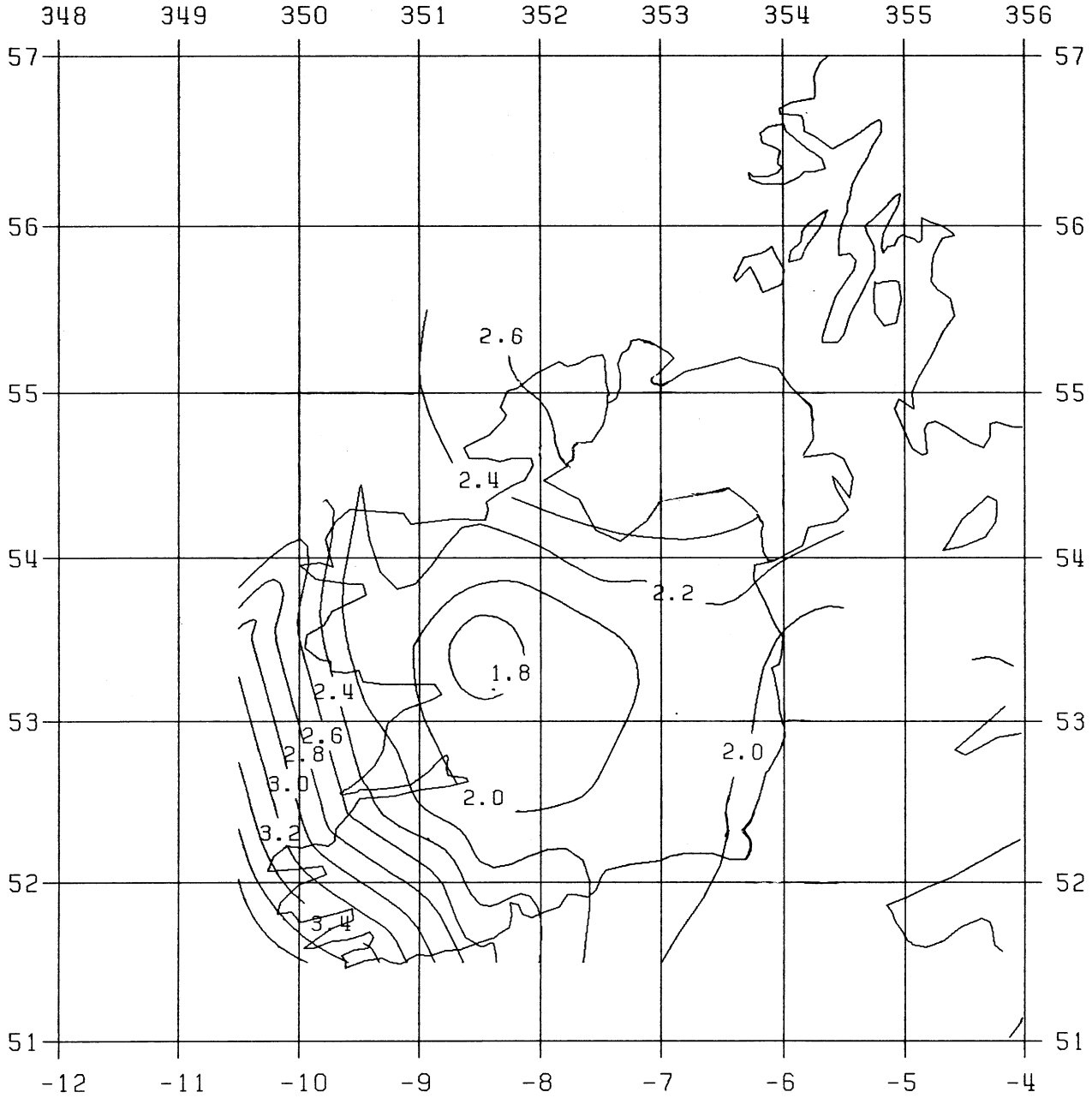

Figure 18.17. DMA-Developed Ireland Datum 1965 Geoid (Referenced to Modified Airy Ellipsoid; Units = Meters)

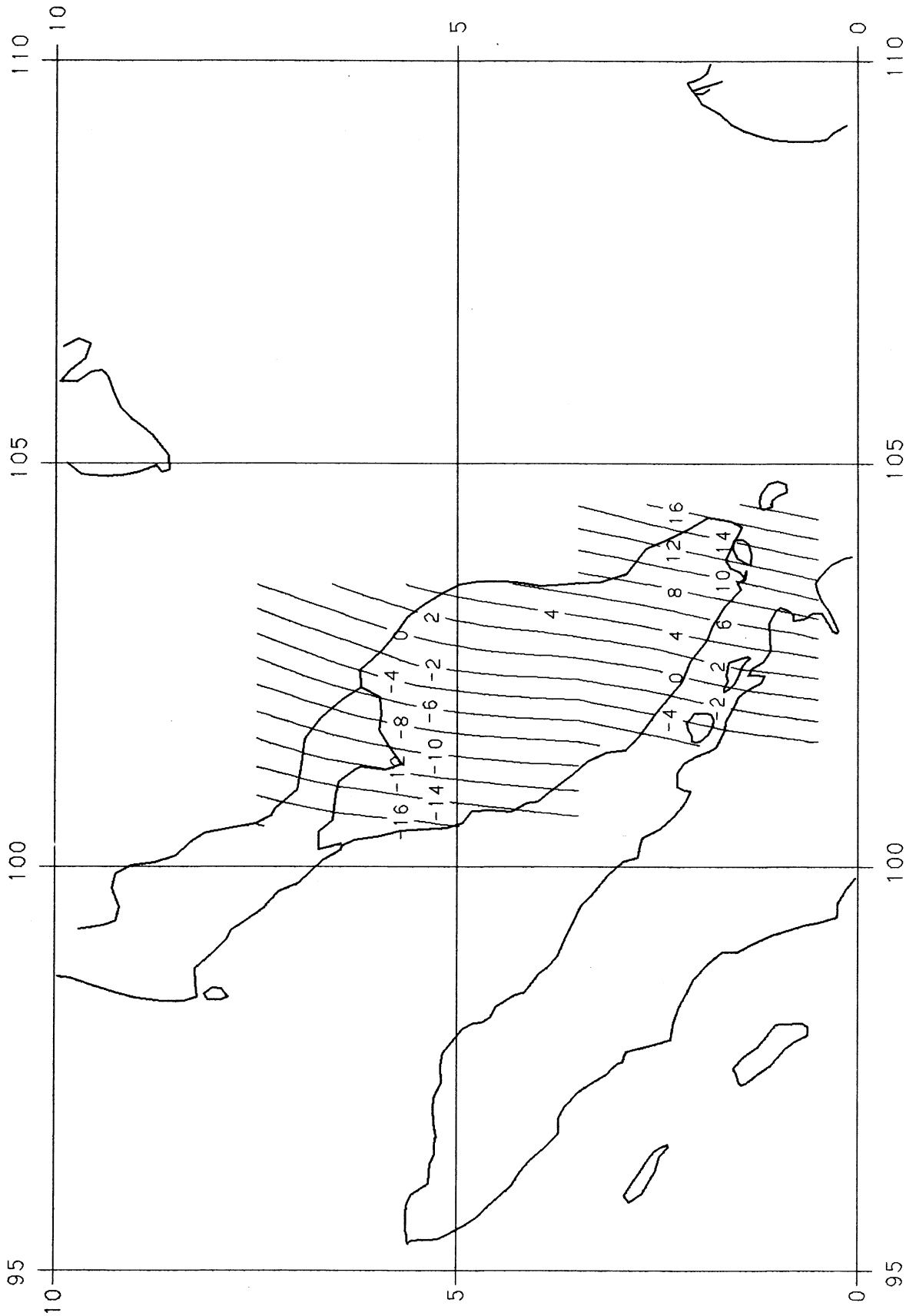

Figure 18.18. DMA-Developed Kertau Datum 1948 Geoid (Referenced to Modified Everest Ellipsoid; Units = Meters)

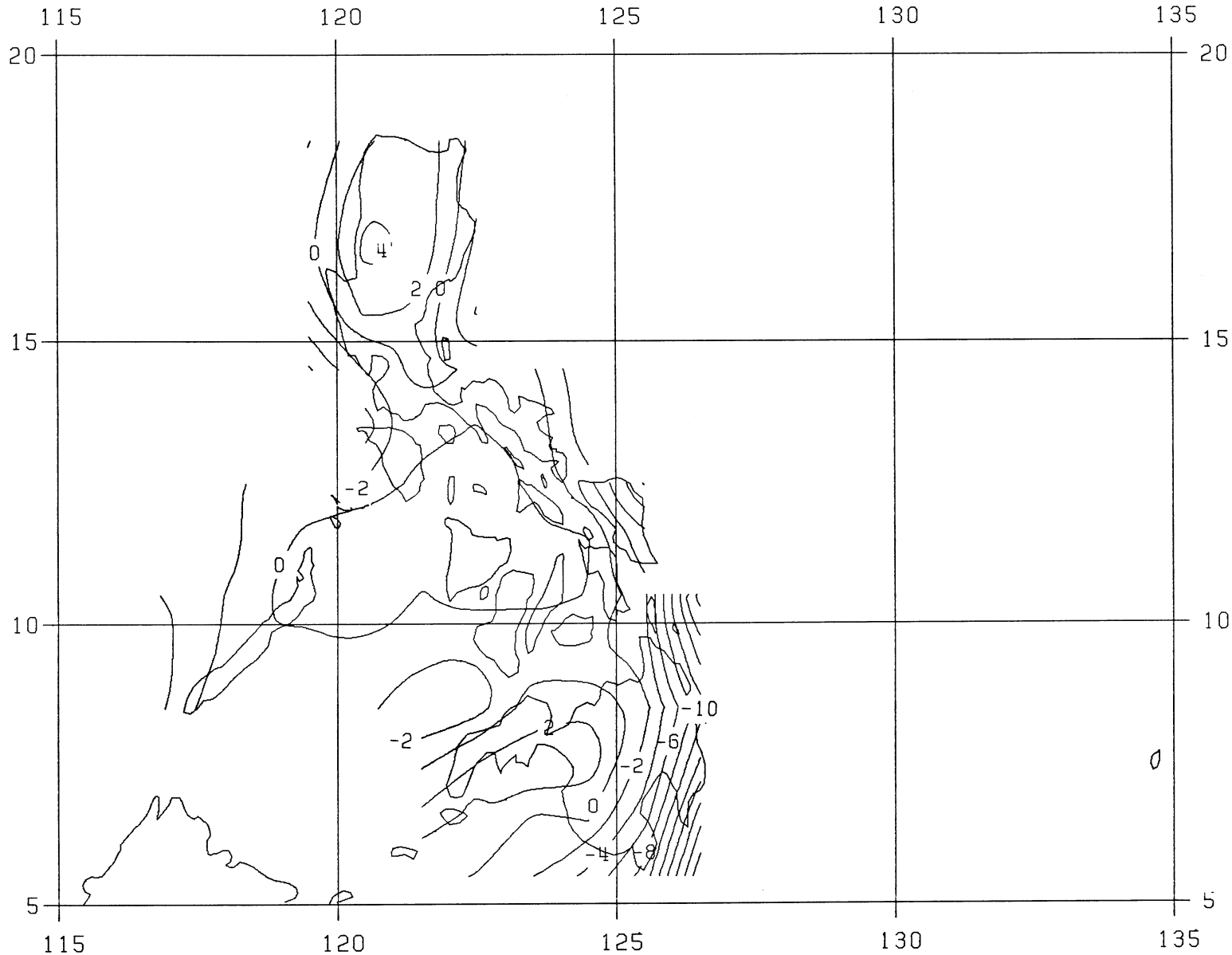

Figure 18.19. DMA-Developed Luzon Datum Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

Figure 18.20. DMA-Developed Merchich Datum Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

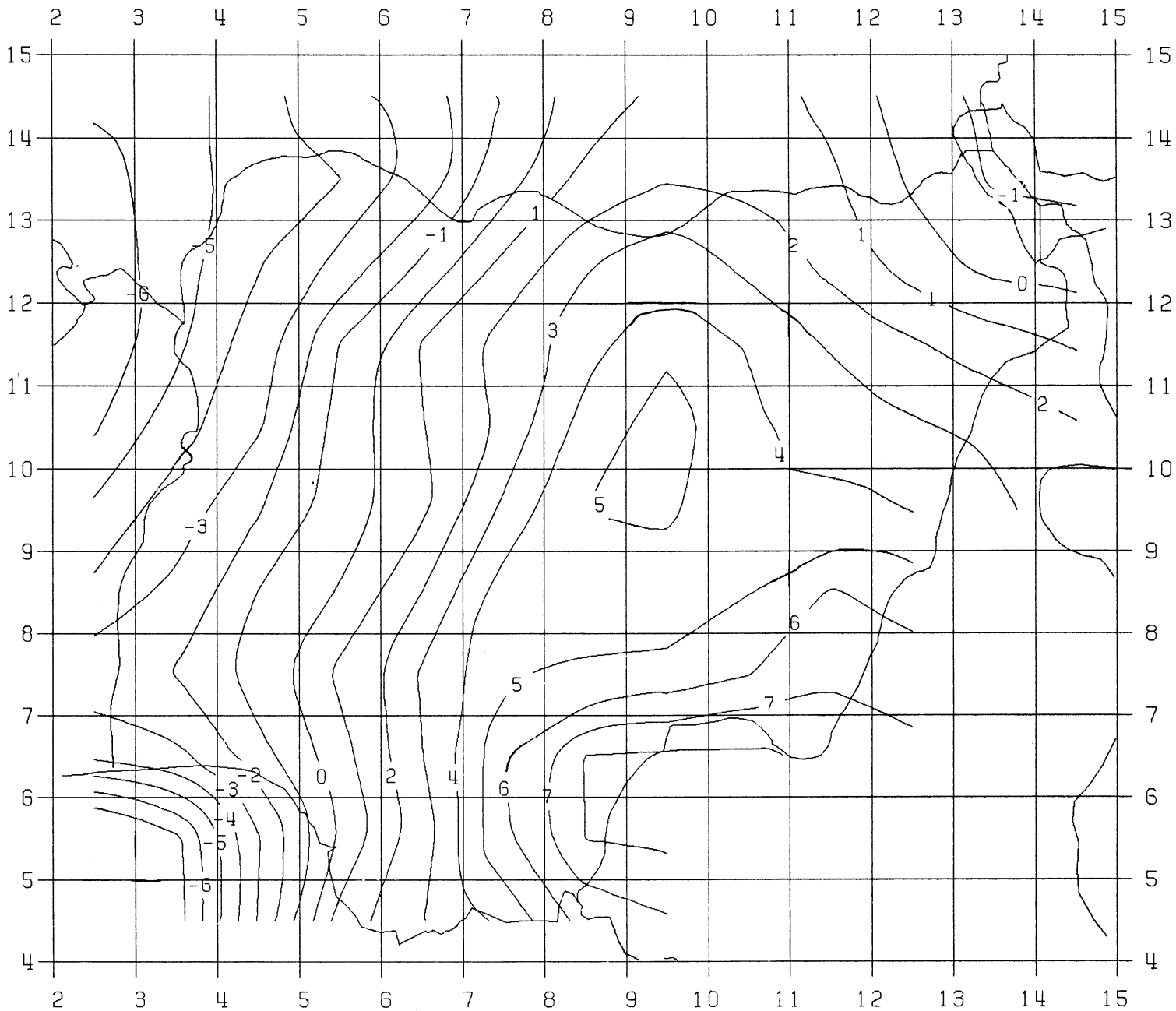

Figure 18.21. DMA-Developed Minna Datum Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

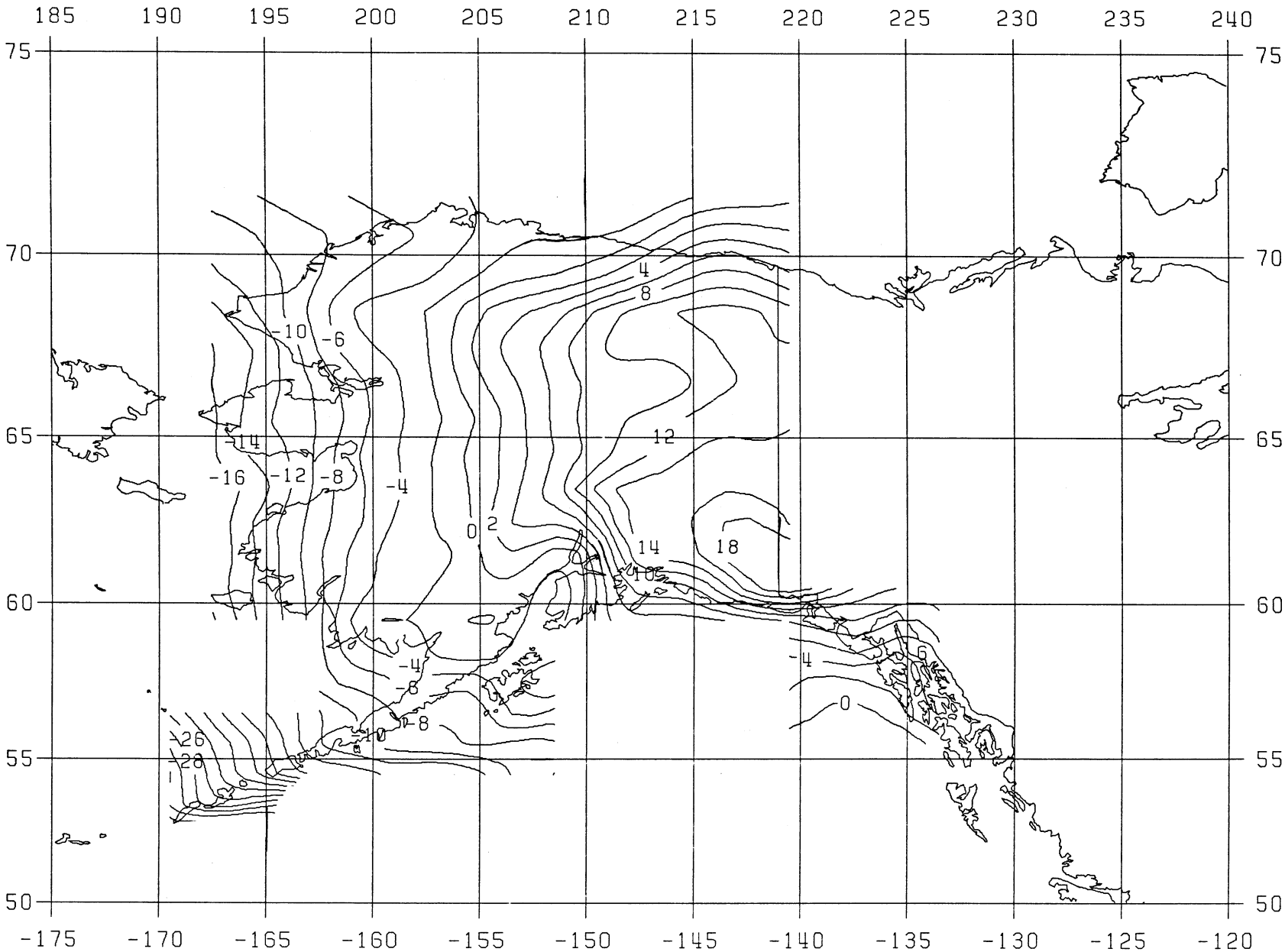

Figure 18.22. DMA-Developed NAD 27 (Alaska) Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

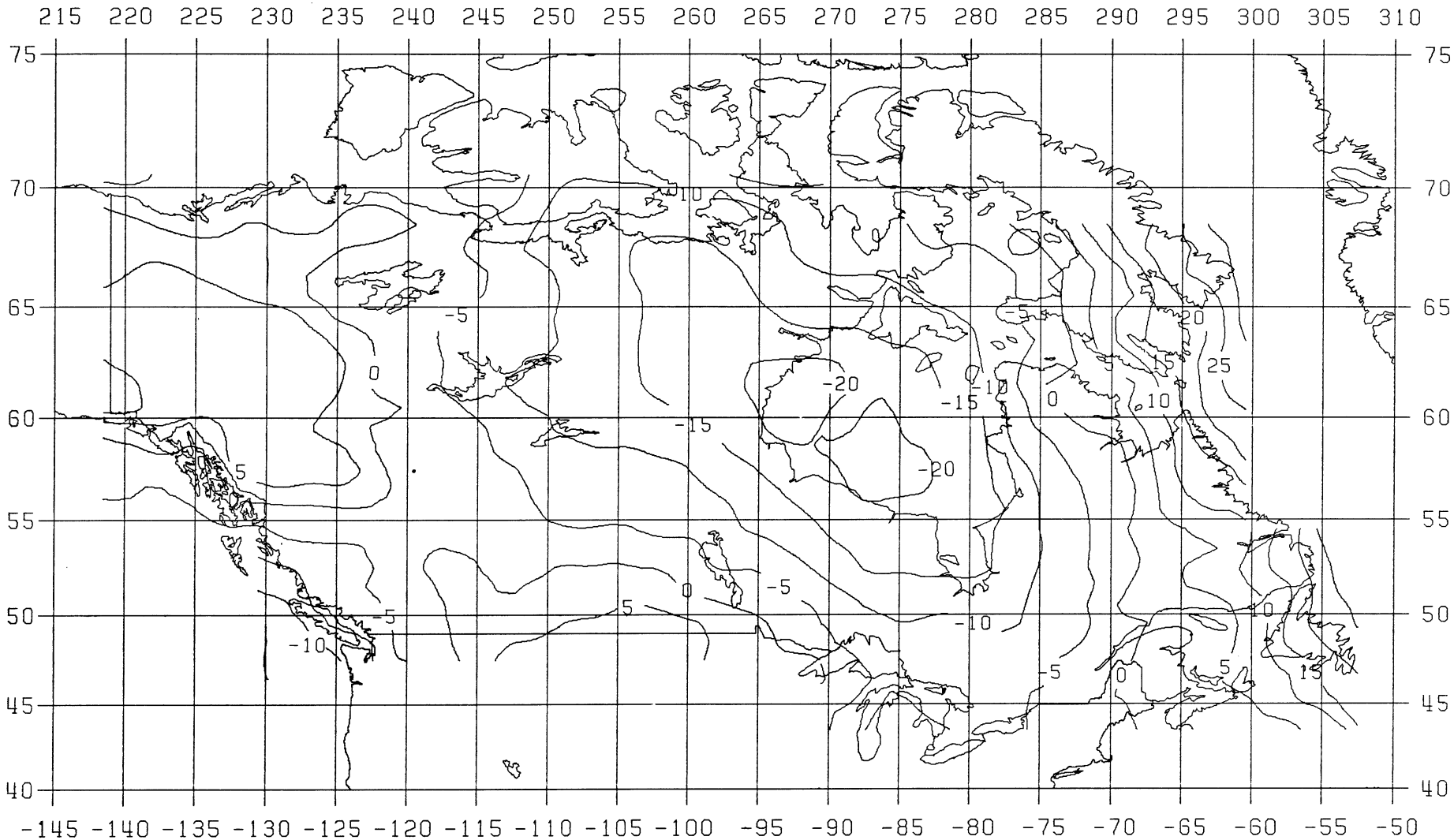

Figure 18.23. DMA-Developed NAD 27 (Canada) Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

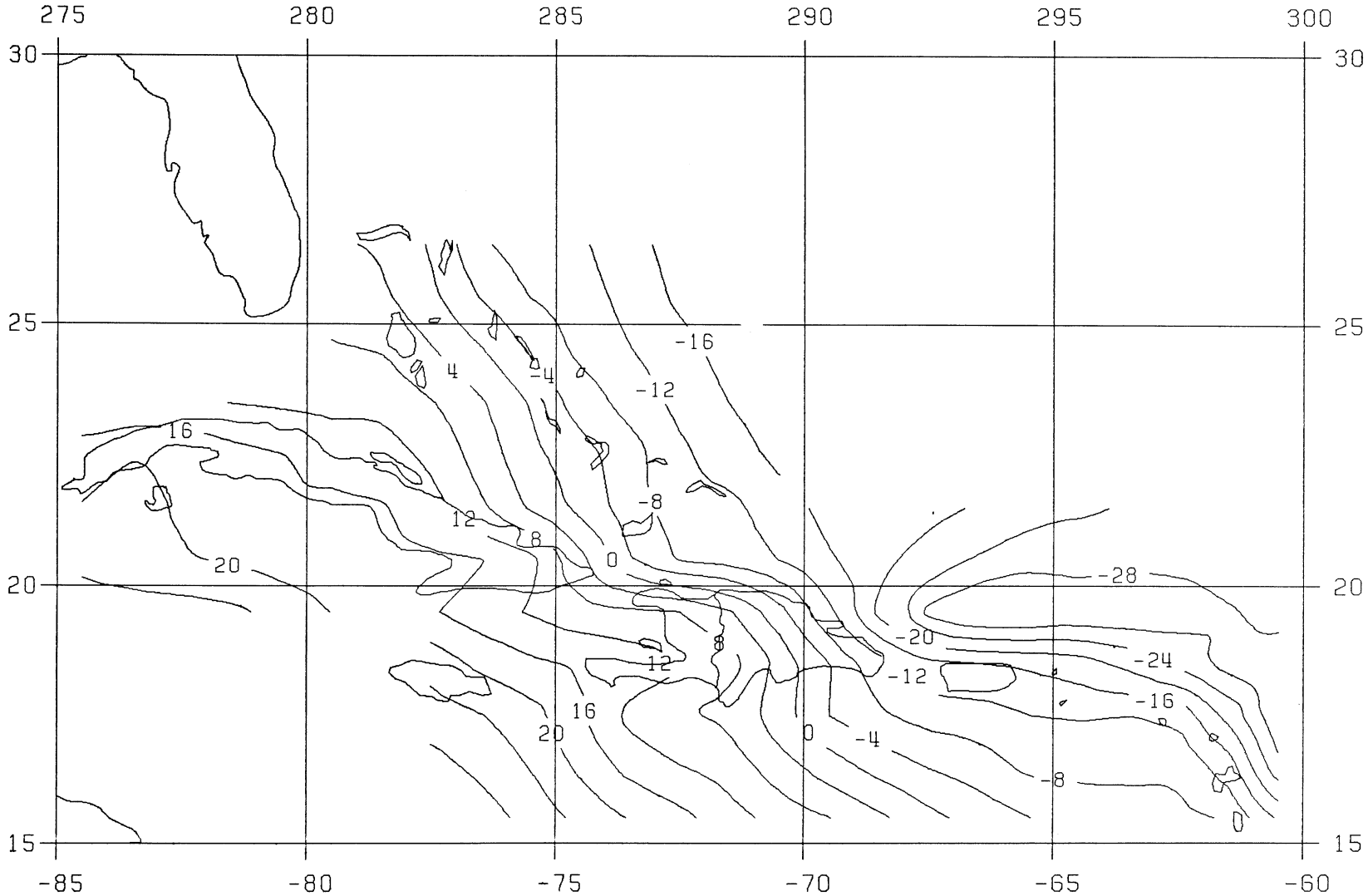

Figure 18.24. DMA-Developed NAD 27 (Caribbean) Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

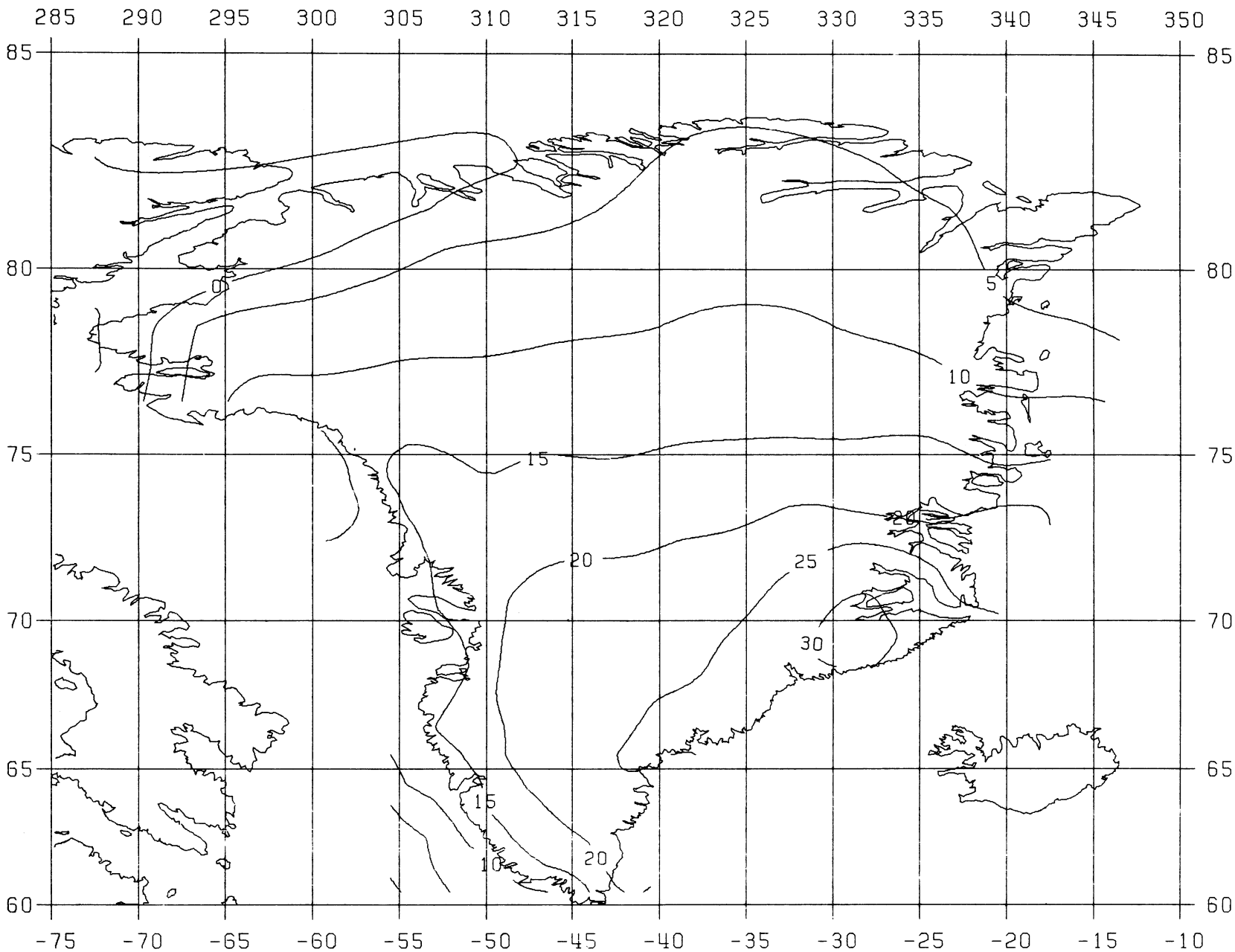

Figure 18.25. DMA-Developed NAD 27 (Greenland/Hayes Peninsula) Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

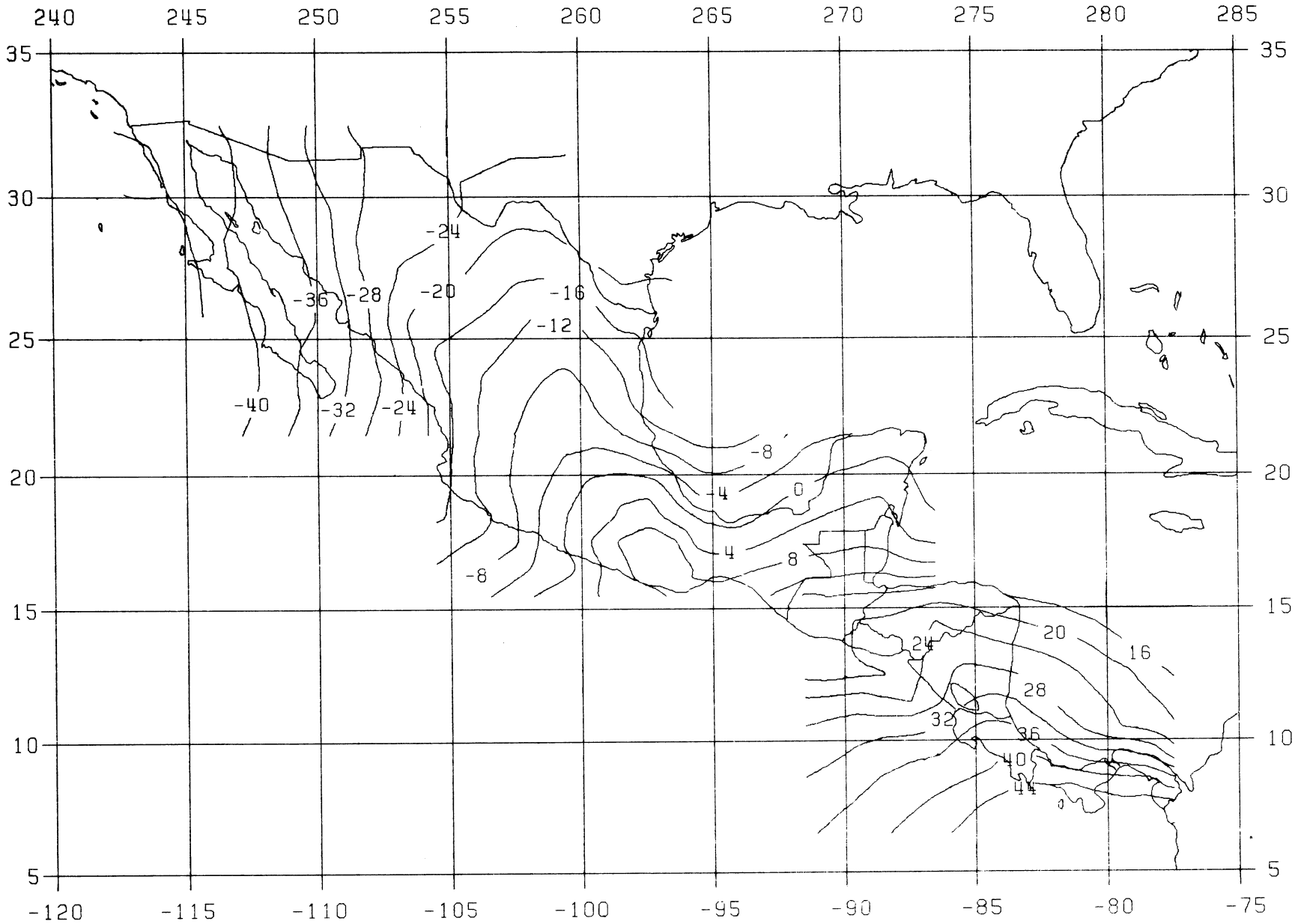

Figure 18.26. DMA-Developed NAD 27 (Mexico, Central America) Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

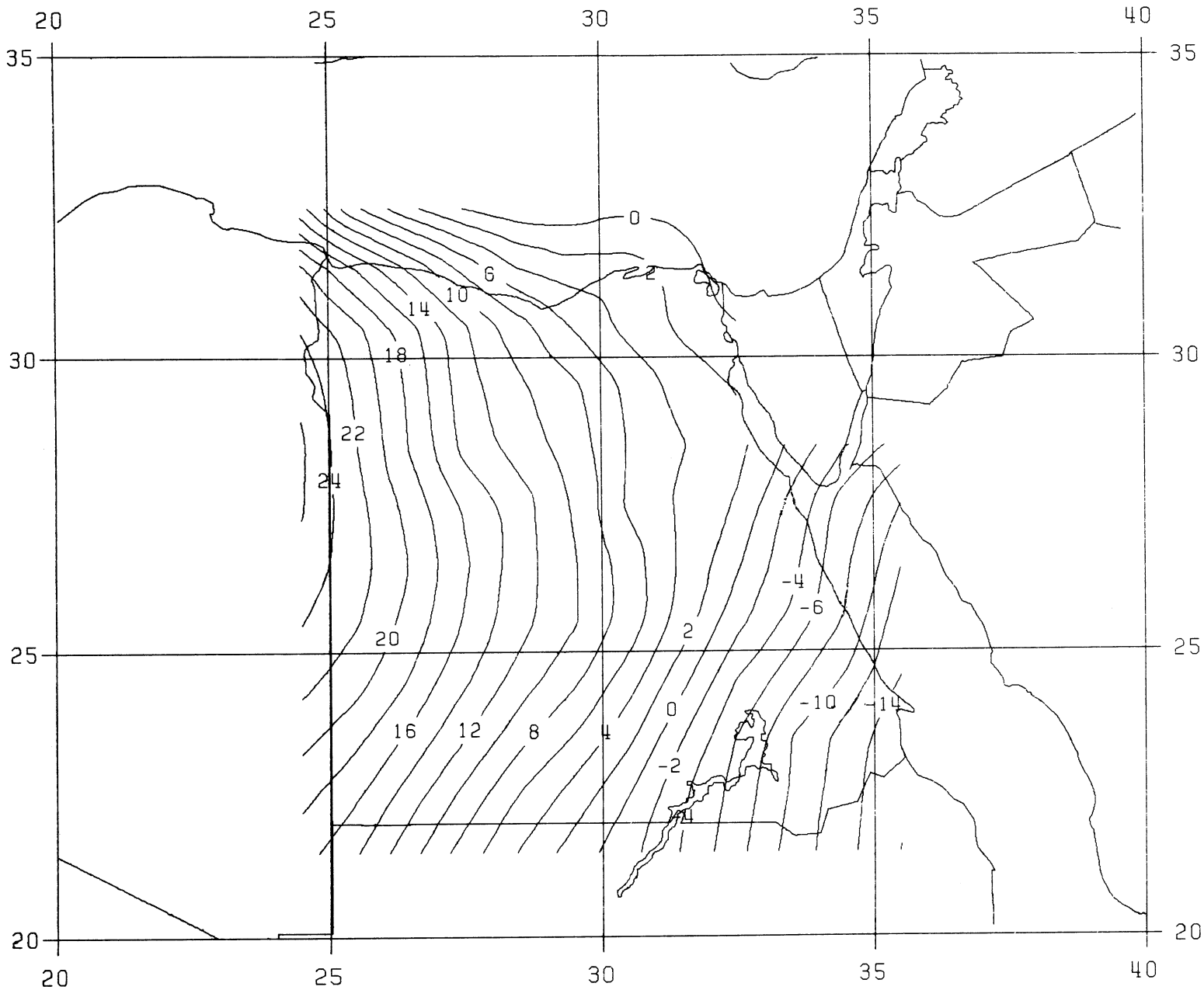

Figure 18.27. DMA-Developed Old Egyptian Datum Geoid (Referenced to Helmert 1906 Ellipsoid; Units = Meters)

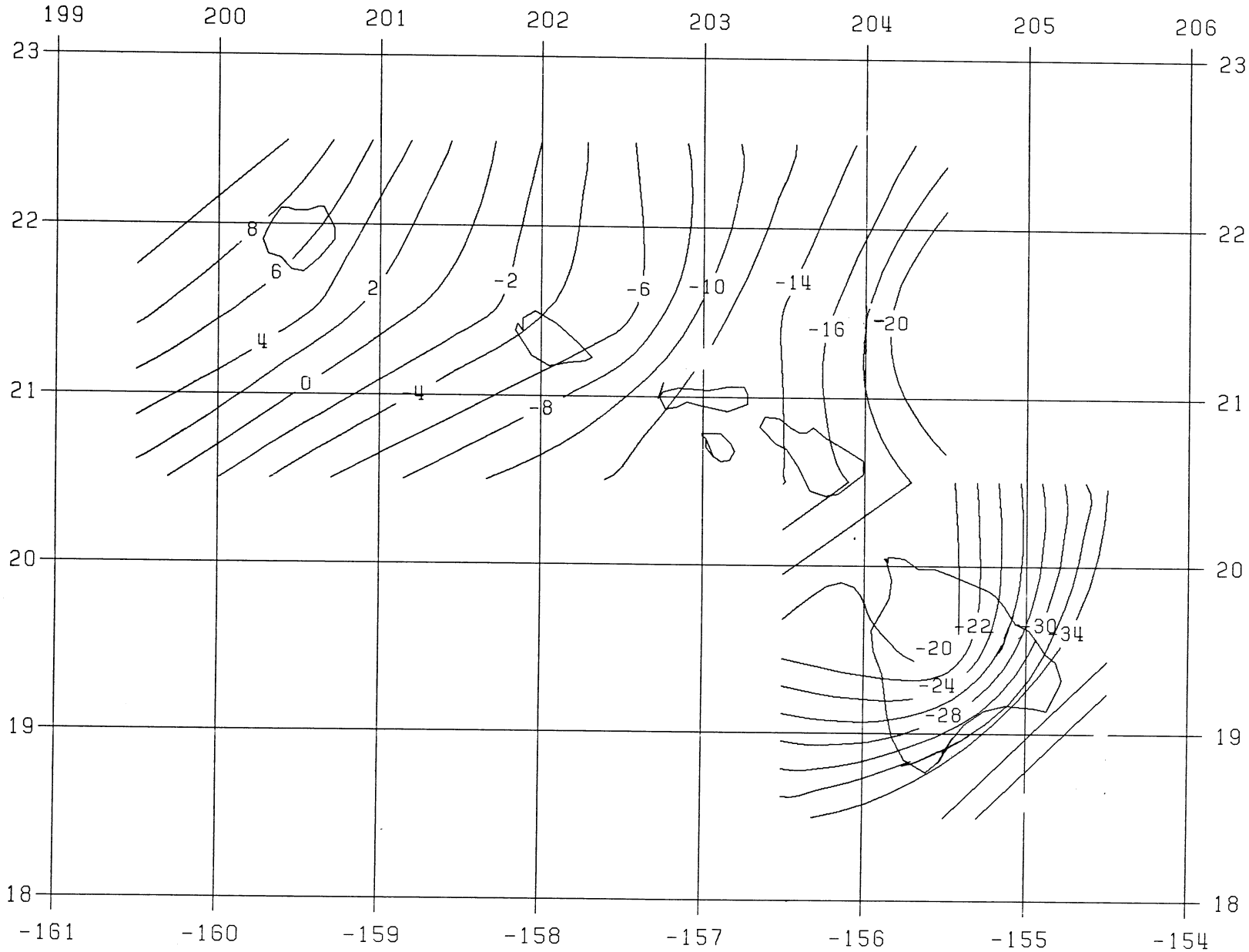

Figure 18.28. DMA-Developed Old Hawaiian Datum Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

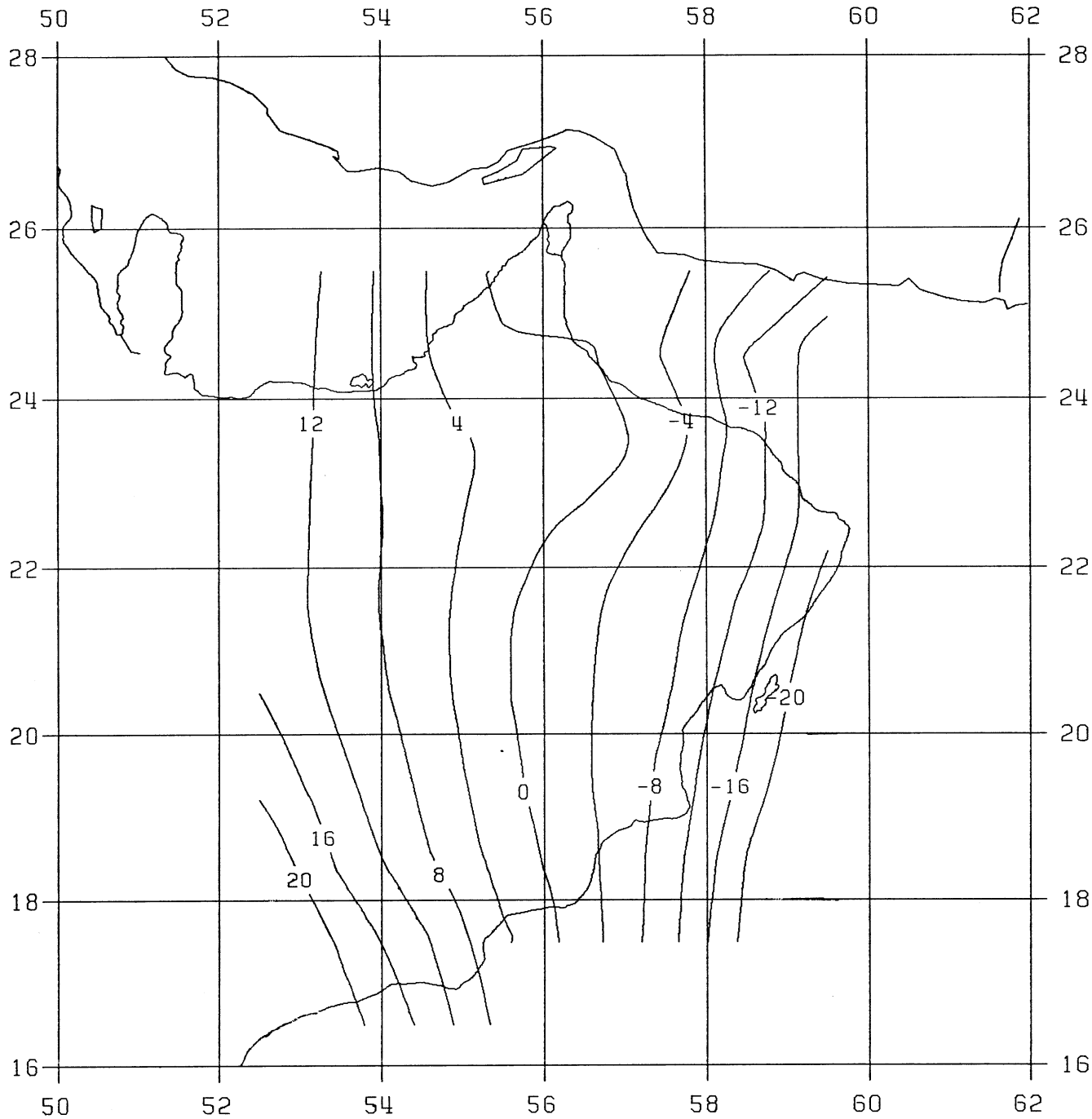

Figure 18.29. DMA-Developed Oman Datum Geoid (Referenced to Clarke 1880 Ellipsoid; Units = Meters)

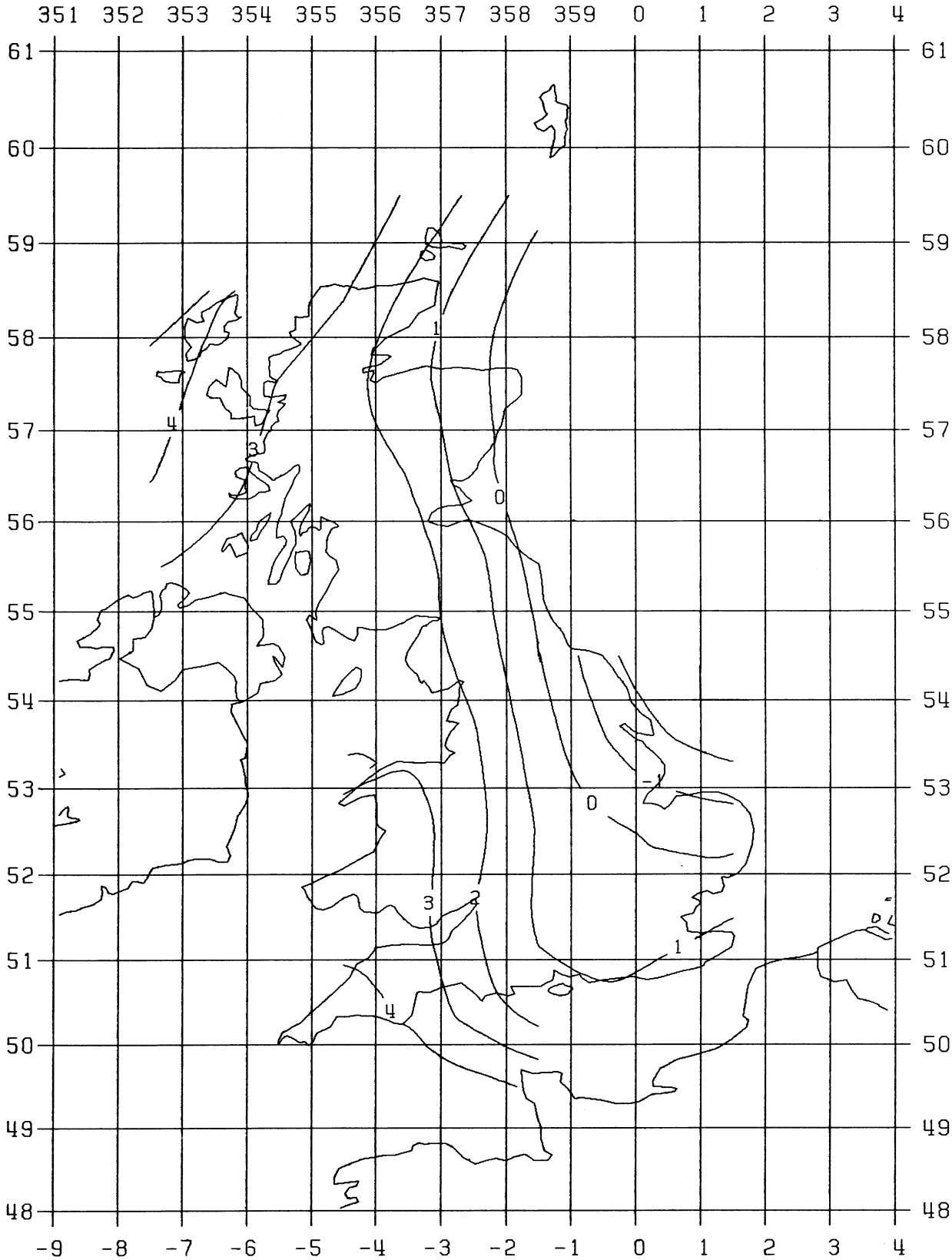

Figure 18.30. DMA-Developed Ordnance Survey of Great Britain 1936 Datum Geoid (Referenced to Airy Ellipsoid; Units = Meters)

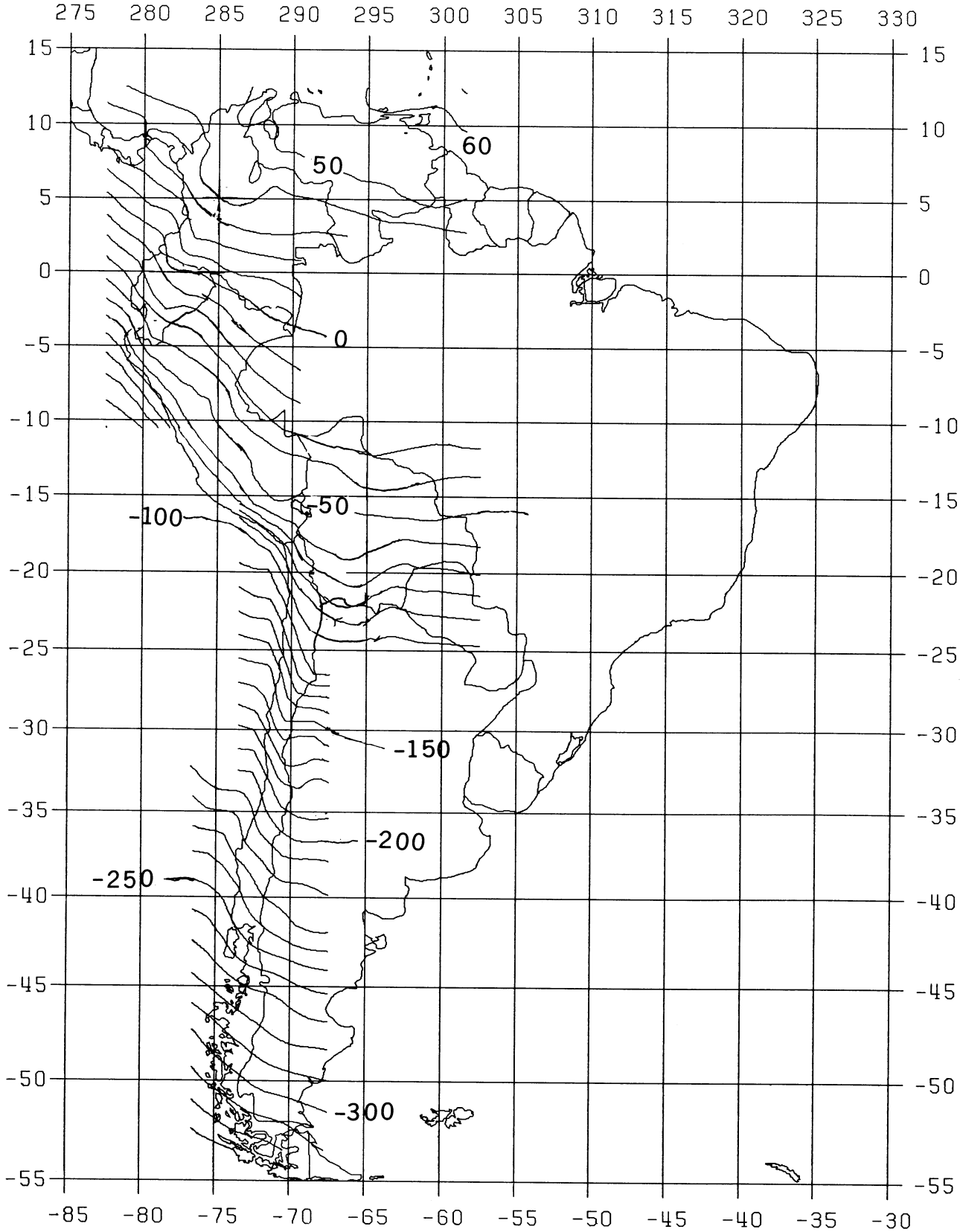

Figure 18.31. DMA-Developed Provisional South American Datum 1956 Geoid (Referenced to International Ellipsoid; Units = Meters)

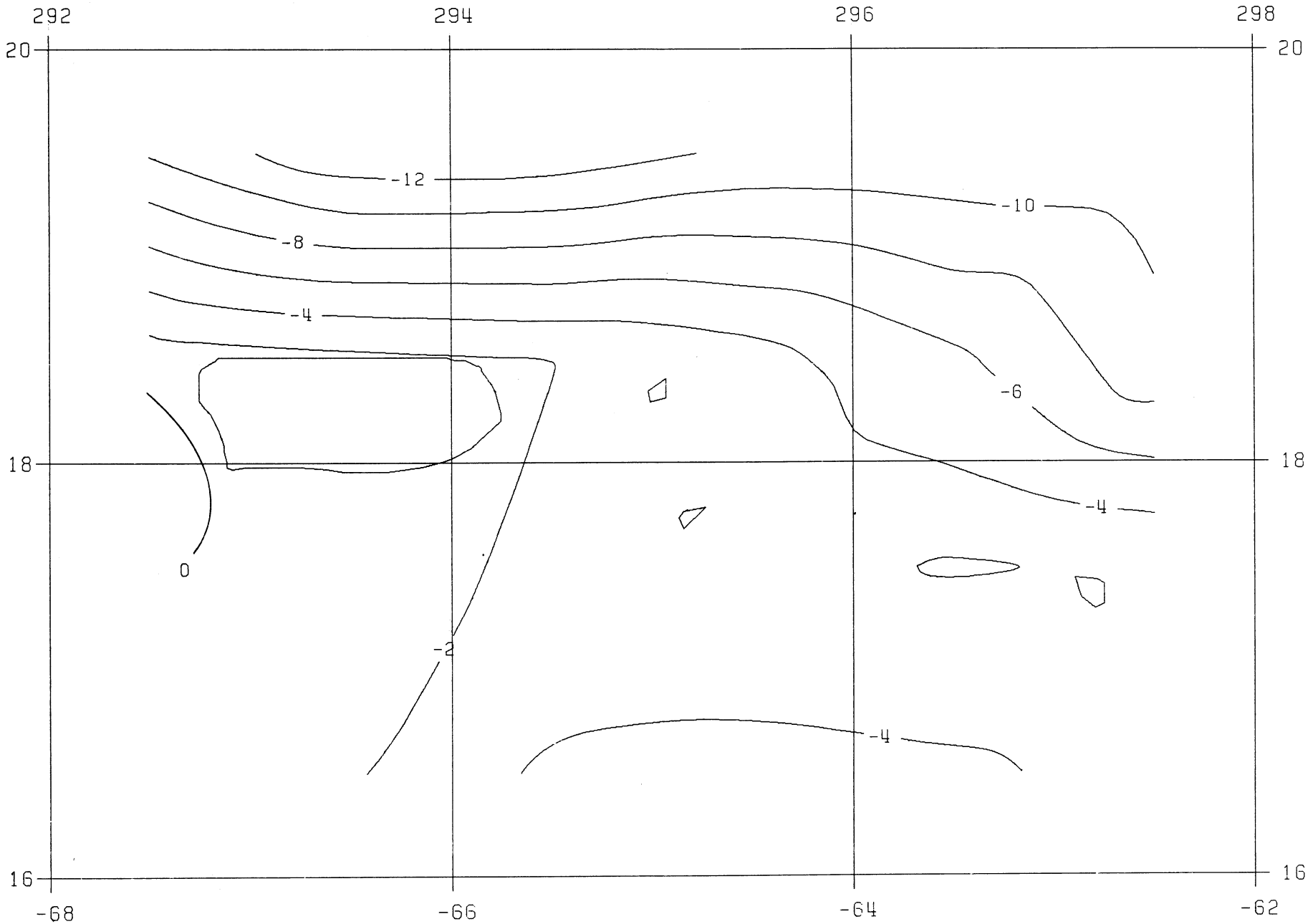

Figure 18.32. DMA-Developed Puerto Rico Datum Geoid (Referenced to Clarke 1866 Ellipsoid; Units = Meters)

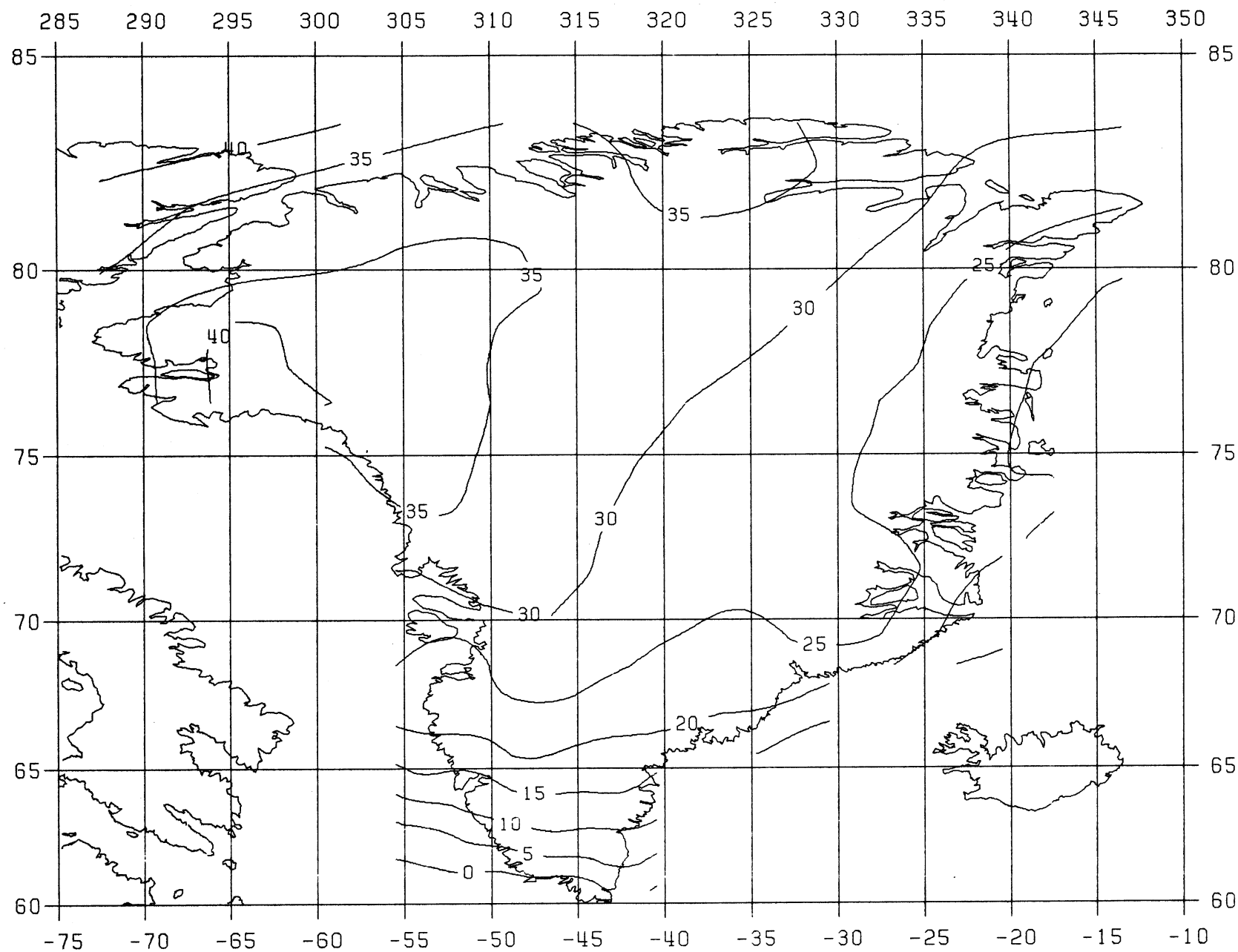

Figure 18.33. DMA-Developed Qornoq Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

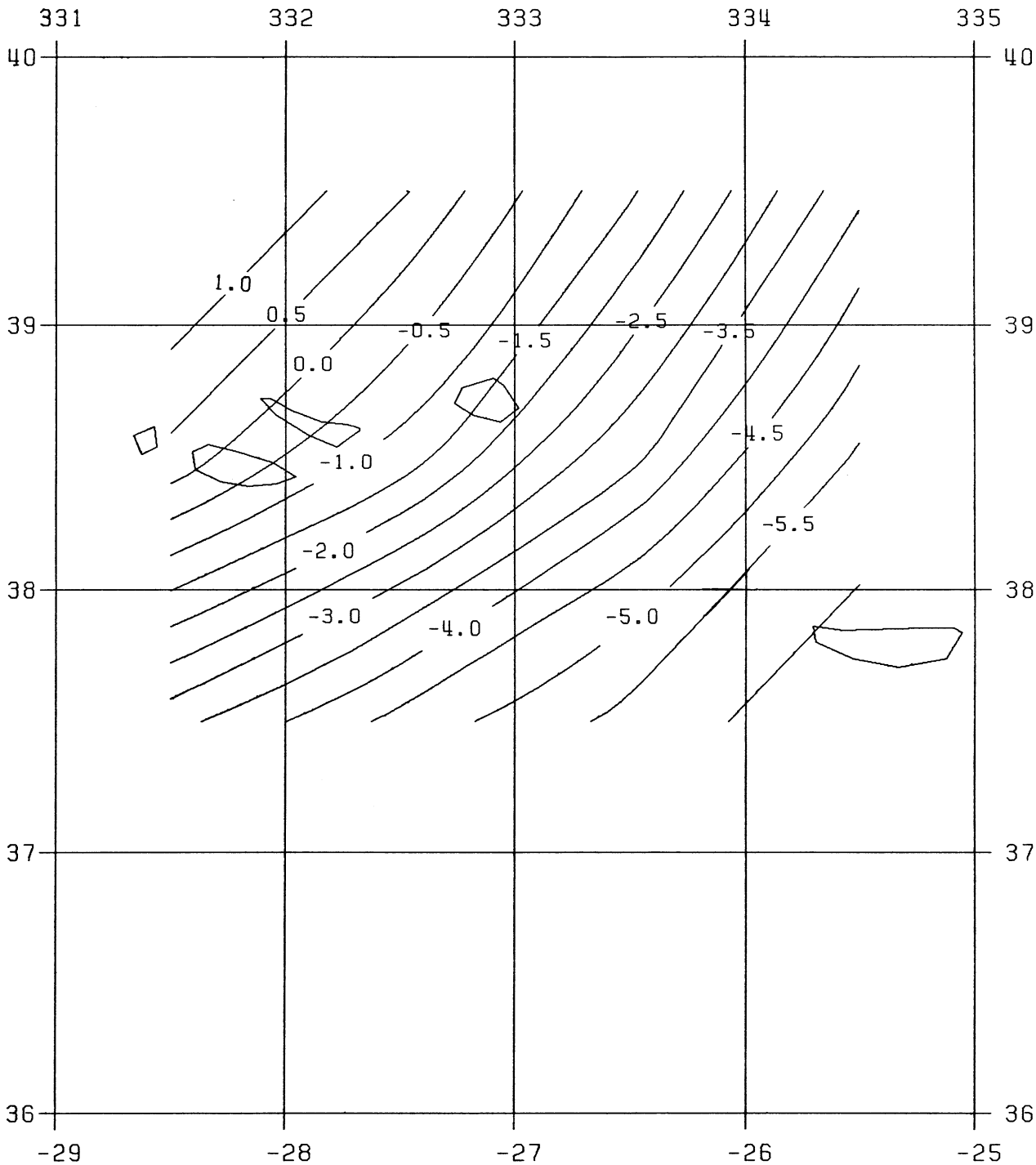

Figure 18.34. DMA-Developed Southwest Base Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

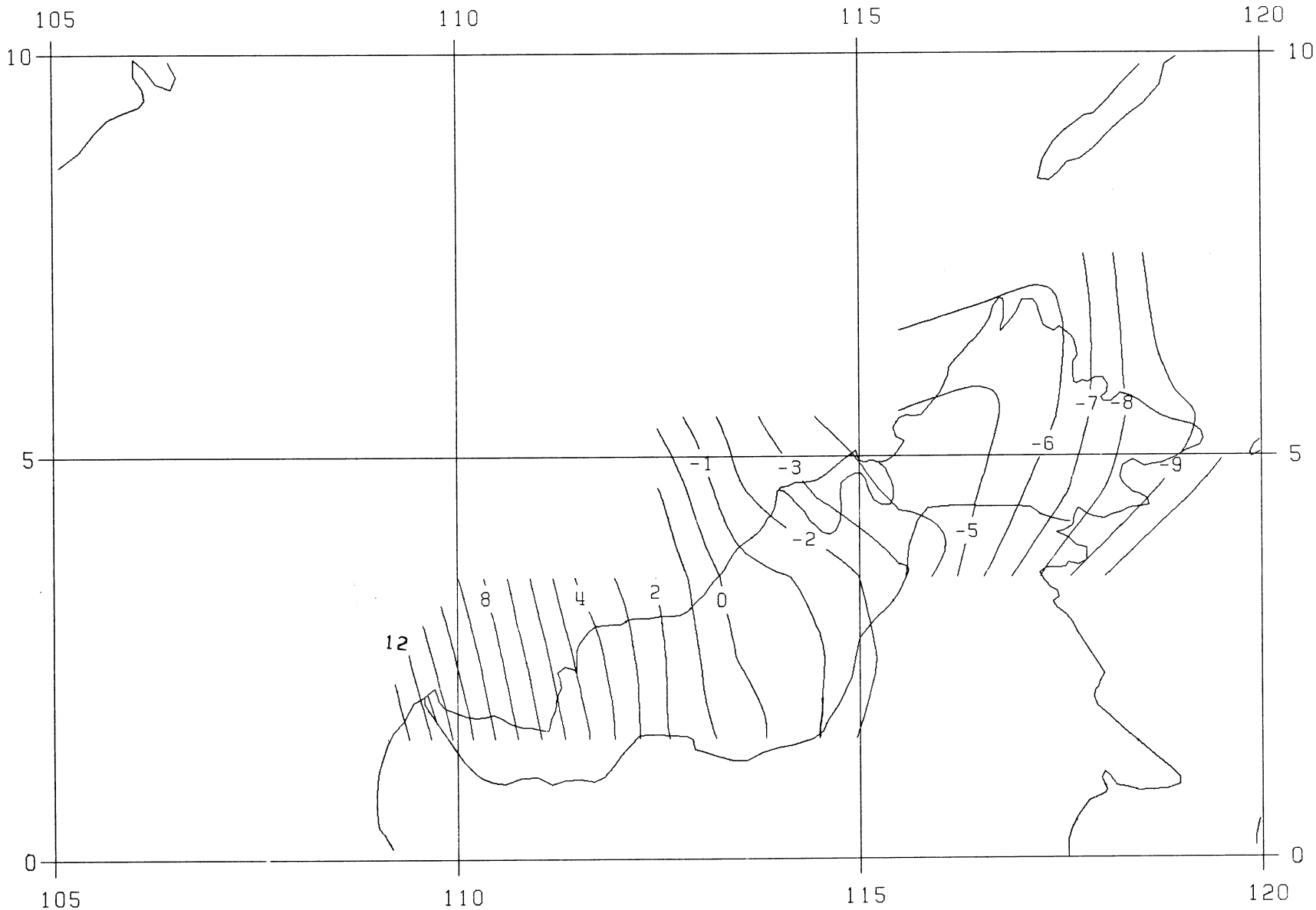

Figure 18.35. DMA-Developed Timbalai Datum 1948 Geoid (Referenced to Everest Ellipsoid; Units = Meters)

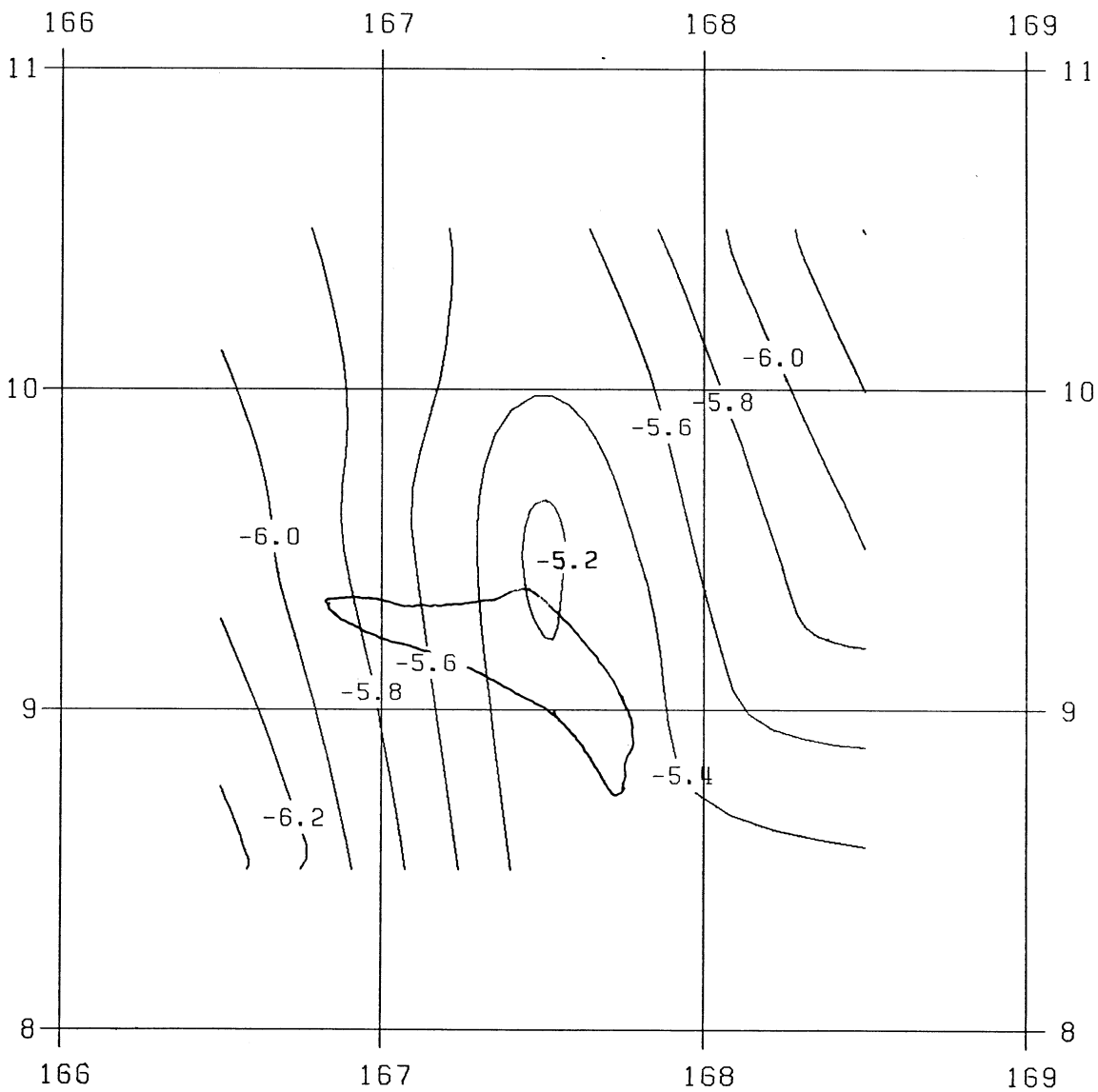

Figure 18.36. DMA-Developed Wake-Eniwetok Datum 1960 Geoid (Referenced to Hough Ellipsoid; Units = Meters)

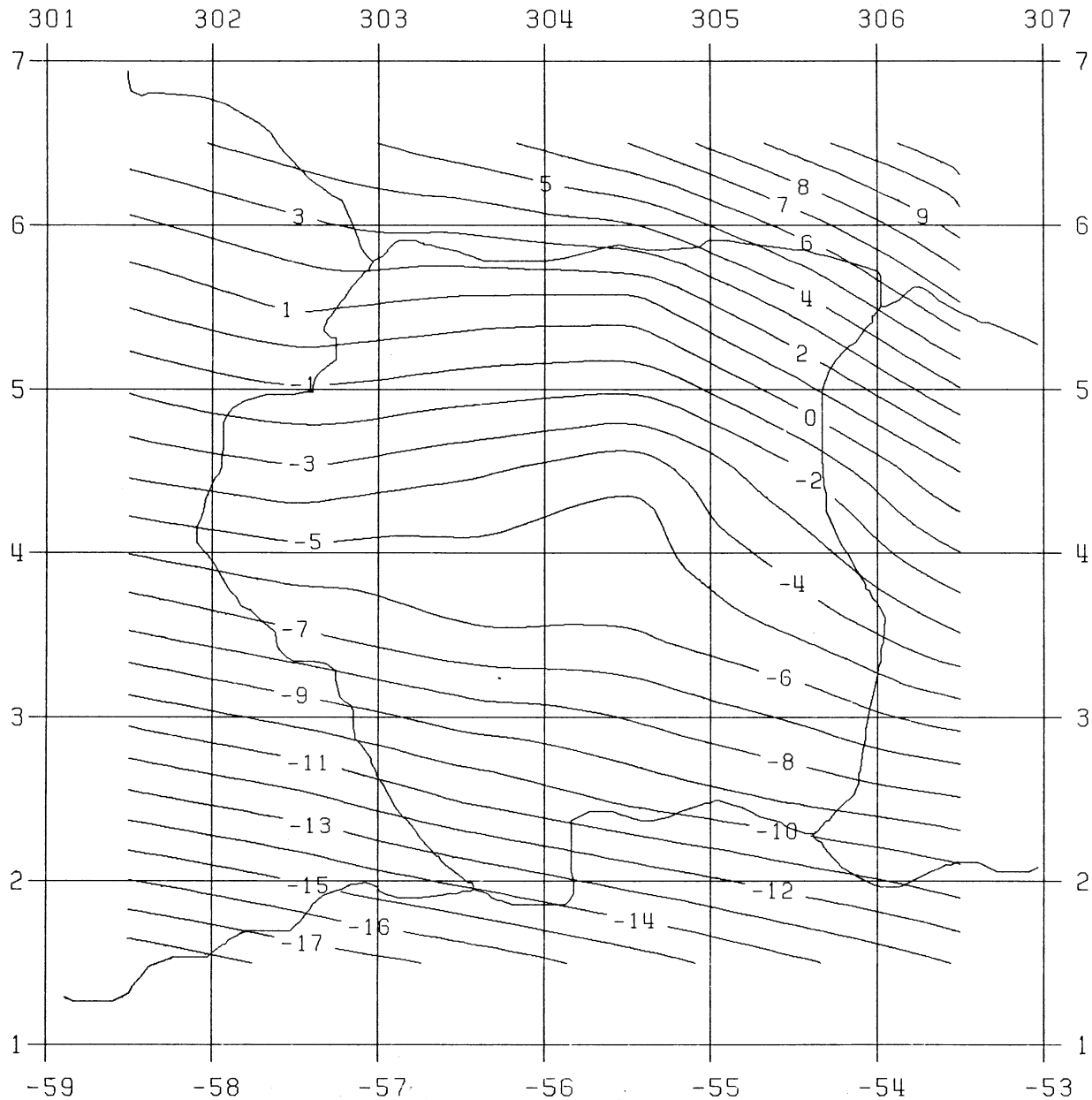

Figure 18.37. DMA-Developed Zanderij Datum Geoid (Referenced to International Ellipsoid; Units = Meters)

SECTION 19

LOCAL GEODETIC SYSTEM-TO-WGS 84

DATUM TRANSFORMATION MULTIPLE REGRESSION EQUATIONS ($\Delta\phi$, $\Delta\lambda$, ΔH)

FOR MAJOR DATUMS *

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* THE $\Delta\phi$, $\Delta\lambda$, ΔH VALUES MAY BE USED IN THE FORMULAS:

$$\phi_{WGS\ 84} = \phi_{LGS} + \Delta\phi$$

$$\lambda_{WGS\ 84} = \lambda_{LGS} + \Delta\lambda$$

$$H_{WGS\ 84} = H_{LGS} + \Delta H$$

ϕ, λ, H = GEODETIC LATITUDE, LONGITUDE, HEIGHT
LGS = LOCAL GEODETIC SYSTEM

NAD 83-TO-WGS 84 DATUM TRANSFORMATION MULTIPLE REGRESSION EQUATIONS WERE NOT DEVELOPED DUE TO THE GOOD AGREEMENT BETWEEN NAD 83 and WGS 84. ALSO, SEE TABLE 7.1.

Table 19.1

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- North American Datum 1927 (NAD 27)* to WGS 84 -

$$\Delta\phi'' = 0.16984 - 0.76173\,U + 0.09585\,V + 1.09919\,U^2 - 4.57801\,U^3 - 1.13239\,U^2V + 0.49831\,V^3 - 0.98399\,U^3V + 0.12415\,UV^3 + 0.11450\,V^4 + 27.05396\,U^5 + 2.03449\,U^4V + 0.73357\,U^2V^3 - 0.37548\,V^5 - 0.14197\,V^6 - 59.96555\,U^7 + 0.07439\,V^7 - 4.76082\,U^8 + 0.03385\,V^8 + 49.04320\,U^9 - 1.30575\,U^6V^3 - 0.07653\,U^3V^9 + 0.08646\,U^4V^9$$

$$\Delta\lambda'' = -0.88437 + 2.05061\,V + 0.26361\,U^2 - 0.76804\,UV + 0.13374\,V^2 - 1.31974\,U^3 - 0.52162\,U^2V - 1.05853\,UV^2 - 0.49211\,U^2V^2 + 2.17204\,UV^3 - 0.06004\,V^4 + 0.30139\,U^4V + 1.88585\,UV^4 - 0.81162\,UV^5 - 0.05183\,V^6 - 0.96723\,UV^6 - 0.12948\,U^3V^5 + 3.41827\,U^9 - 0.44507\,U^8V + 0.18882\,UV^8 - 0.01444\,V^9 + 0.04794\,UV^9 - 0.59013\,U^9V^3$$

$$\Delta H_m = -36.526 + 3.900\,U - 4.723\,V - 21.553\,U^2 + 7.294\,UV + 8.886\,V^2 - 8.440\,U^2V - 2.930\,UV^2 + 56.937\,U^4 - 58.756\,U^3V - 4.061\,V^4 + 4.447\,U^4V + 4.903\,U^2V^3 - 55.873\,U^6 + 212.005\,U^5V + 3.081\,V^6 - 254.511\,U^7V - 0.756\,V^8 + 30.654\,U^8V - 0.122\,UV^9$$

* Contiguous United States (CONUS)

Table 19.1 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- North American Datum 1927 (NAD 27)* to WGS 84 -

In the preceding equations:

$$U = K (\phi - 37)$$

$$V = K (\lambda - 265)$$

$$K = 0.05235988$$

ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)

λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 447, 425, and 428 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.3 m; λ: ±1.3 m; H (geodetic height): ±1.2 m

Test Case:

Input data for NAD 27 test point:	ϕ = 34°47'08.833"N	$\Delta\phi$ = 0.356"
	λ = 273°25'07.825"E	$\Delta\lambda$ = 0.080"
		ΔH = -38.06 m

*Contiguous United States (CONUS)

Table 19.2

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- South American Datum 1969 (SAD 69) to WGS 84 -

$$
\begin{aligned}
\Delta\phi'' = \; & -1.67504 - 0.05209\,U + 0.25158\,V + 1.10149\,U^2 + 0.24913\,UV - 1.00937\,U^2V - 0.74977\,V^3 \\
& - 1.54090\,U^4 + 0.14474\,V^4 + 0.47866\,U^5 + 0.36278\,U^3V^2 - 1.29942\,UV^4 + 0.30410\,V^5 \\
& + 0.87669\,U^6 - 0.27950\,U^5V - 0.46367\,U^7 + 4.31466\,U^4V^3 + 2.09523\,U^2V^5 + 0.85556\,UV^6 \\
& - 0.17897\,U^8 - 0.57205\,UV^7 + 0.12327\,U^9 - 0.85033\,U^6V^3 - 4.86177\,U^4V^5 + 0.06085\,U^9V \\
& - 0.21518\,U^3V^8 + 0.31053\,U^5V^7 - 0.09228\,U^8V^5 - 0.22996\,U^9V^5 + 0.58774\,U^6V^9 \\
& + 0.87562\,U^9V^7 + 0.39001\,U^8V^9 - 0.81697\,U^9V^9
\end{aligned}
$$

$$
\begin{aligned}
\Delta\lambda'' = \; & -1.77967 + 0.40405\,U + 0.50268\,V - 0.05387\,U^2 - 0.12837\,UV - 0.54687\,U^2V \\
& - 0.17056\,V^3 - 0.14400\,U^3V + 0.11351\,U^5V - 0.62692\,U^3V^3 - 0.01750\,U^8 + 1.18616\,U^3V^5 \\
& + 0.01305\,U^9 + 1.01360\,U^7V^3 - 0.29059\,U^8V^3 + 5.12370\,U^6V^5 - 5.09561\,U^7V^5 - 5.27168\,U^6V^7 \\
& + 4.04265\,U^7V^7 - 1.62710\,U^8V^7 + 1.68899\,U^9V^7 + 2.07213\,U^8V^9 - 1.76074\,U^9V^9
\end{aligned}
$$

$$
\begin{aligned}
\Delta H_m = \; & 9.570 - 6.834\,U - 30.016\,V - 4.015\,U^2 - 20.812\,UV - 21.963\,U^3 + 16.430\,U^2V + 18.938\,UV^2 \\
& + 64.770\,V^3 + 54.885\,U^3V - 42.988\,UV^3 + 16.338\,U^5 - 15.557\,U^4V - 20.455\,U^2V^3 - 27.201\,UV^4 \\
& - 83.152\,V^5 + 0.520\,U^6 - 40.493\,U^5V + 101.490\,UV^5 - 3.423\,U^7 + 32.506\,V^7 + 20.338\,U^7V \\
& - 42.081\,UV^7 + 1.670\,U^8V + 23.697\,U^3V^6 + 17.596\,U^2V^7 - 4.342\,U^9V - 42.782\,U^3V^7 \\
& + 5.778\,U^6V^5 - 1.734\,U^8V^4 - 6.902\,U^5V^8 + 16.305\,U^5V^9 - 4.599\,U^8V^7
\end{aligned}
$$

Table 19.2 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- South American Datum 1969 (SAD 69) to WGS 84 -

In the preceding equations:

$$U = K (\phi + 20)$$

$$V = K (\lambda - 300)$$

$$K = 0.05235988$$

ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)

λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 133, 134, and 132 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.4 m; λ: ±1.5 m; H (geodetic height): ±1.8 m.

Test Case:

Input data for SAD 69 test point:	ϕ = -31°56'33.954"S	$\Delta\phi$ = -1.356"
	λ = 294°53'41.342"E	$\Delta\lambda$ = -2.158"
		ΔH = 20.27 m

Table 19.3

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- European Datum 1950 (ED 50)* to WGS 84 -

$$\Delta\phi'' = -2.65261 + 2.06392\,U + 0.77921\,V + 0.26743\,U^2 + 0.10706\,UV + 0.76407\,U^3 - 0.95430\,U^2V + 0.17197\,U^4 + 1.04974\,U^4V - 0.22899\,U^5V^2 - 0.05401\,V^8 - 0.78909\,U^9 - 0.10572\,U^2V^7 + 0.05283\,UV^9 + 0.02445\,U^3V^9$$

$$\Delta\lambda'' = -4.13447 - 1.50572\,U + 1.94075\,V - 1.37600\,U^2 + 1.98425\,UV + 0.30068\,V^2 - 2.31939\,U^3 - 1.70401\,U^4 - 5.48711\,UV^3 + 7.41956\,U^5 - 1.61351\,U^2V^3 + 5.92923\,UV^4 - 1.97974\,V^5 + 1.57701\,U^6 - 6.52522\,U^3V^3 + 16.85976\,U^2V^4 - 1.79701\,UV^5 - 3.08344\,U^7 - 14.32516\,U^6V + 4.49096\,U^4V^4 + 9.98750\,U^8V + 7.80215\,U^7V^2 - 2.26917\,U^2V^7 + 0.16438\,V^9 - 17.45428\,U^4V^6 - 8.25844\,U^9V^2 + 5.28734\,U^8V^3 + 8.87141\,U^5V^7 - 3.48015\,U^9V^4 + 0.71041\,U^4V^9$$

$$\Delta H_m = 36.393 - 28.239\,U - 16.575\,V + 12.889\,U^2 + 9.678\,UV + 2.497\,V^2 + 6.850\,U^3 - 5.219\,U^4 - 2.765\,UV^4 + 7.029\,U^2V^5 - 5.205\,U^6V^2 - 0.938\,UV^9$$

---

* Western Europe Only

Table 19.3 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- European Datum 1950 (ED 50)* to WGS 84 -

In the preceding equations:

$$U = K (\phi - 52)$$

$$V = K (\lambda - 10)$$

$$K = 0.05235988$$

ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)

λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 103, 106, and 110 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.1 m; λ: ±1.0 m; H (geodetic height): ±1.4 m.

Test Case:

Input data for ED 50 test point:	ϕ = 46°41'42.893"N	$\Delta\phi$ = -3.081"
	λ = 13°54'54.088"E	$\Delta\lambda$ = -3.486"
		ΔH = 41.21 m

* Western Europe Only

[Revised: 30 September 1988]

Table 19.4

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- European Datum 1950 (ED 50)* to WGS 84 -

$$\Delta\phi'' = -2.85283 + 1.03873\,U + 0.37255\,V + 0.37918\,U^2 - 0.08366\,V^2 + 2.79510\,U^2V^2 + 3.95456\,U^4V + 3.25139\,U^2V^3 - 2.24817\,U^2V^9$$

$$\Delta\lambda'' = -5.27853 - 1.18834\,U + 0.74334\,V - 0.73180\,U^2 - 0.79053\,U^2V - 0.17149\,V^9 + 95.11569\,U^8V^2 - 15.47503\,U^4V^6$$

$$\Delta H_m = 45.252 - 9.464\,U - 7.532\,V - 4.551\,U^2 + 13.000\,UV + 6.317\,U^2V + 65.157\,U^3V^2$$

In the preceding equations:

$U = K\,(\phi - 54)$
$V = K\,(\lambda - 0)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 67, 68, and 68 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±0.7 m; λ: ±1.0 m; H (geodetic height): ±1.0 m.

Test Case:

Input data for ED 50 test point:

ϕ = 49°42'40.562"N $\Delta\phi$ = -3.348"

λ = 357°48'11.987"E $\Delta\lambda$ = -5.019"

ΔH = 51.05 m

* United Kingdom (UK)/Ireland; ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates

[Revised: 30 September 1988]

Table 19.5

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- European Datum 1950 (ED 50)* to WGS 84 -

$$\Delta\phi'' = -2.85015 + 0.92725\,U + 0.28642\,V - 7.65303\,U^3V - 7.96754\,U^3V^2 + 1.74155\,U^6 + 14.59802\,U^5V + 2.56074\,U^2V^5 - 638.59010\,U^8V^7$$

$$\Delta\lambda'' = -5.27005 - 1.18558\,U + 0.85411\,V - 0.85857\,U^2 - 1.86437\,U^2V + 43.65251\,U^4V^5 - 2.52387\,V^9 + 92.91554\,U^8V^2$$

$$\Delta H_m = 45.473 - 9.046\,U - 4.695\,V - 7.034\,U^2 + 13.533\,UV - 13.235\,U^2V + 52.433\,U^3V^2$$

In the preceding equations:

$U = K\,(\phi - 54)$
$V = K\,(\lambda - 0)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 56, 57, and 57 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±0.8 m; λ: ±1.0 m; H (geodetic height): ±1.0 m.

Test Case:

Input data for ED 50 test point:

ϕ = 49°42'40.562"N $\Delta\phi$ = -3.378"
λ = 357°48'11.987"E $\Delta\lambda$ = -5.014"
ΔH = 50.96 m

* United Kingdom (UK) Only; ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates. The equations in Table 19.4 are recommended for all transformations for United Kingdom (UK)/Ireland.

[Revised: 30 September 1988

Table 19.6

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Tokyo Datum (TD) to WGS 84 -

$$\Delta\phi'' = 11.42838 + 0.38110\,U + 0.66055\,V - 2.85156\,U^2 - 7.90920\,U^3 + 2.66055\,U^2V - 1.44720\,UV^2 - 0.55880\,V^3 + 17.02465\,U^4 - 13.83455\,U^3V + 2.24425\,UV^3 + 4.26478\,U^5 + 10.19286\,U^4V - 12.27058\,U^3V^2 + 1.72169UV^4 - 10.70332\,U^6 + 9.42547\,U^4V^2 - 0.04957\,U^3V^3 - 1.63710\,U^7 - 3.31782\,U^4V^3 + 5.58416\,U^3V^4 + 2.17642\,U^8 - 3.44749\,U^4V^4 - 0.18249\,V^8 - 0.40958\,U^2V^7 - 0.08997\,V^9 + 0.75251\,U^3V^7 - 0.14797\,U^2V^8 - 0.00866\,U^9V^5$$

$$\Delta\lambda'' = -9.41485 - 4.14394\,V - 0.20672\,UV - 1.37944\,V^2 - 1.23235\,U^3 - 0.83040\,U^2V + 5.62308\,V^3 + 1.80683\,V^4 - 4.51075\,V^5 + 0.09944\,U^6 - 0.91183\,V^6 + 0.90813\,U^7 + 0.28770\,U^2V^5 + 1.48962\,V^7 + 0.16266\,V^8 - 0.27918\,U^9 - 0.16036\,V^9 - 0.03918\,U^5V^8 + 0.01027\,U^7V^8$$

$$\Delta H_m = 17.498 - 5.767\,U - 30.032\,V + 93.585\,U^2 - 23.478\,UV + 20.307\,U^2V + 11.444\,UV^2 + 12.581\,V^3 - 235.503\,U^4 + 48.615\,U^3V + 76.860\,U^5 - 2.569\,V^5 + 170.295\,U^6 - 39.287\,U^5V - 73.837\,U^7 - 11.695\,U^3V^4 - 38.249\,U^8 + 9.382\,U^7V + 18.230\,U^9 + 3.445\,U^4V^5 + 0.329\,UV^9 - 0.147\,U^3V^9$$

Table 19.6 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Tokyo Datum (TD) to WGS 84 -

In the preceding equations:

$$U = K (\phi - 35)$$

$$V = K (\lambda - 135)$$

$$K = 0.15707963$$

ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)

λ = geodetic longitude, local geodetic system, in degrees and part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 56,55, and 58 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±2.1 m; λ: ±2.3 m; H (geodetic height): ±2.8 m.

Test Case:

Input data for TD test point:

ϕ = 40°42'38.260"N $\Delta\phi$ = 9.634"

λ = 141°22'23.979"E $\Delta\lambda$ = -12.598"

ΔH = 20.99 m

Table 19.7

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Australian Geodetic Datum 1966 (AGD 66) to WGS 84 -

$$\Delta\phi'' = 5.19238 + 0.12666\,U + 0.52309\,V - 0.42069\,U^2 - 0.39326\,UV + 0.93484\,U^2V + 0.44249\,UV^2 - 0.30074\,UV^3 + 1.00092\,U^5 - 0.07565\,V^6 - 1.42988\,U^9 - 16.06639\,U^4V^5 + 0.07428\,V^9 + 0.24256\,UV^9 + 39.27946\,U^6V^7 - 62.06403\,U^7V^8 + 89.19184\,U^9V^8$$

$$\Delta\lambda'' = 4.69250 - 0.87138\,U - 0.50104\,V + 0.12678\,UV - 0.23076\,V^2 - 0.61098\,U^2V - 0.38064\,V^3 + 2.89189\,U^6 + 5.26013\,U^2V^5 - 2.97897\,U^8 + 5.43221\,U^3V^5 - 3.40748\,U^2V^6 + 0.07772\,V^8 + 1.08514\,U^8V + 0.71516\,UV^8 + 0.20185\,V^9 + 5.18012\,U^2V^8 - 1.72907\,U^3V^8 - 1.24329\,U^2V^9$$

$$\Delta H_m = 6.953 + 54.753\,U + 38.295\,V + 15.913\,U^2 + 12.922\,UV - 2.616\,V^2 - 24.663\,U^3 - 13.250\,U^2V + 105.716\,U^3V^2 - 467.812\,U^3V^3 + 79.981\,U^7V - 1225.777\,U^4V^4 + 2184.222\,U^3V^5 + 353.713\,U^2V^6 + 1026.749\,U^4V^5 - 228.175\,U^2V^7 - 20.283\,UV^8 + 1202.073\,U^4V^6 - 3578.264\,U^3V^7 - 513.229\,U^2V^8 - 12.141\,UV^9 - 1407.128\,U^5V^6 + 522.507\,U^8V^4 + 1519.599\,U^3V^9 - 6318.177\,U^6V^9$$

Table 19.7 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Australian Geodetic Datum 1966 (AGD 66) to WGS 84 -

In the preceding equations:

$$U = K (\phi + 27)$$

$$V = K (\lambda - 134)$$

$$K = 0.05235988$$

ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)

λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 133, 135, and 127 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.2 m; λ: ±1.3 m; H (geodetic height): ±1.1 m.

Test Case:

Input data for AGD 66 test point:

ϕ = -17°00'32.776"S $\Delta\phi$ = 5.480"

λ = 144°11'37.245"E $\Delta\lambda$ = 3.922"

ΔH = 57.28 m

Table 19.8

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Australian Geodetic Datum 1984 (AGD 84) to WGS 84 -

$$\Delta\phi'' = 5.20604 + 0.25225\ U + 0.58528\ V - 0.41584\ U^2 - 0.38620\ UV - 0.06820\ V^2 + 0.38699\ U^2V + 0.07934\ UV^2 + 0.37714\ U^4 - 0.52913\ U^4V + 0.38095\ V^7 + 0.68776\ U^2V^6 - 0.03785\ V^8 - 0.17891\ U^9 - 4.84581\ U^2V^7 - 0.35777\ V^9 + 4.23859\ U^2V^9$$

$$\Delta\lambda'' = 4.67877 - 0.73036\ U - 0.57942\ V + 0.28840\ U^2 + 0.10194\ U^3 - 0.27814\ UV^2 - 0.13598\ V^3 + 0.34670\ UV^3 - 0.46107\ V^4 + 1.29432\ U^2V^3 + 0.17996\ UV^4 - 1.13008\ U^2V^5 - 0.46832\ U^8 + 0.30676\ V^8 + 0.31948\ U^9 + 0.16735\ V^9 - 1.19443\ U^3V^9$$

$$\Delta H_m = 7.083 + 55.757\ U + 36.306\ V + 21.288\ U^2 + 15.111\ UV - 3.814\ V^2 - 34.056\ U^3 + 3.325\ V^3 - 18.113\ U^2V^2 + 54.055\ U^3V^2 - 201.077\ U^6V - 34.759\ U^2V^5 - 30.667\ UV^6 - 167.018\ U^6V^2 + 333.184\ U^8V + 20.740\ UV^8 - 3.650\ V^9 - 662.590\ U^3V^7 + 546.536\ U^3V^9$$

Table 19.8 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Australian Geodetic Datum 1984 (AGD 84) to WGS 84 -

In the preceding equations:

$$U = K (\phi + 27)$$

$$V = K (\lambda - 134)$$

$$K = 0.05235988$$

ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)

λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 112, 112, and 111 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.0 m; λ: ±1.0 m; H (geodetic height): ±1.5 m

Test Case:

Input data for AGD 84 test point:

ϕ = -20°38'00.673"S $\Delta\phi$ = 5.505"

λ = 144°24'29.288"E $\Delta\lambda$ = 4.109"

ΔH = 47.84 m

Table 19.9

RMS Differences Between "True" WGS 84 Coordinates
and WGS 84 Coordinates Computed Using Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations

Local Geodetic System	- RMS Differences - "True" Minus Computed Coordinates			Comparison Points (Average Number)
	$\Delta\phi$	$\Delta\lambda$	ΔH	
NAD 27*	±1.3 m	±1.3 m	±1.2 m	433
SAD 69	1.4	1.5	1.8	133
ED 50 (Western Europe)**	1.1	1.0	1.4	106
ED 50 (UK/Ireland)***	0.7	1.0	1.0	68
ED 50 (UK Only)***	0.8	1.0	1.0	57
TD	2.1	2.3	2.8	56
AGD 66	1.2	1.3	1.1	132
AGD 84	1.0	1.0	1.5	112

* Contiguous United States (CONUS)

** Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland

*** European Datum 1950 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates

[Revised: 30 September 1988]

SECTION 20

LOCAL GEODETIC SYSTEM-TO-WGS 84

DATUM TRANSFORMATION MULTIPLE REGRESSION EQUATIONS ($\Delta\phi$, $\Delta\lambda$, ΔH)

FOR REMAINDER OF 83 LOCAL GEODETIC SYSTEMS*

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* EXCEPT FOR EUROPEAN DATUM 1979 (SINCE IT DOES NOT REPLACE ED 50). CONSTANT OR AVERAGE $\Delta\phi$, $\Delta\lambda$, ΔH VALUES ARE GIVEN IN TABLE 20.46 FOR THOSE LOCAL GEODETIC SYSTEMS HAVING ONLY THE SMALL NUMBER OF COLOCATED DOPPLER AND LOCAL GEODETIC SYSTEM STATIONS INDICATED (1, 2, or 3). ALSO, SEE TABLE 7.1. THE EQUATION PORTION OF THE FOOTNOTE TO PAGE 19-1 ALSO APPLIES HERE (SECTION 20).

Table 20.1

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Adindan Datum* to WGS 84 -

$$\Delta\phi'' = 2.30939 - 2.70532\,U - 0.17616\,U^2 - 0.67784\,UV + 2.14942\,UV^2 - 6.21315\,U^3V + 0.11956\,V^4 - 2.65405\,U^3V^2 + 0.44562\,U^6 + 8.77907\,U^5V + 4.61321\,U^3V^3 + 0.70866\,U^2V^4 + 1.15691\,U^6V^2 + 6.39994\,U^7V^2 + 4.95968\,U^6V^3 - 3.17763\,U^4V^5 + 3.41973\,U^6V^4 + 2.24544\,U^4V^7 - 11.02072\,U^9V^3 - 9.13270\,U^8V^4 - 0.40499\,U^4V^9$$

$$\Delta\lambda'' = 2.46978 + 0.82797\,V + 0.10716\,U^2 - 0.10258\,UV + 0.12861\,V^2 - 0.46939\,U^2V - 0.22576\,U^3V - 0.04250\,V^5 - 0.40529\,U^2V^4 - 0.20142\,U^3V^8 + 0.08317\,U^3V^9$$

$$\Delta H_m = 2.337 + 6.056\,U + 9.628\,V - 7.824\,U^2 + 30.221\,U^3 - 4.046\,U^2V - 5.632\,UV^2 - 25.258\,U^5 - 9.483\,U^2V^3 - 5.105\,U^5V + 21.890\,U^4V^2 - 37.142\,U^5V^2 + 17.646\,U^5V^3 + 27.471\,U^9V^2$$

In the preceding equations:

$U = K\,(\phi - 14)$
$V = K\,(\lambda - 32)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 44, 47, and 50 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.5 m; λ: ±1.3 m; H (geodetic height): ±1.2 m.

Test Case:

Input data for Adindan Datum test point:	ϕ = 9°05'12.250"N	$\Delta\phi$ = 3.860"
	λ = 36°34'48.852"E	$\Delta\lambda$ = 2.899"
		ΔH = -0.90 m

* Ethiopia, Sudan

Table 20.2

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Arc Datum 1950* to WGS 84 -

$$\Delta\phi'' = -2.90105 - 1.41963\,U - 0.07116\,V + 0.41503\,U^2 - 0.48095\,UV - 0.37682\,V^2 - 0.43296\,U^2V - 0.59626\,UV^2 - 0.41464\,U^4 + 0.06665\,U^2V^2 + 0.86933\,UV^3 + 0.38753\,U^3V^2 + 0.32332\,UV^4 - 0.09534\,V^5 + 0.10867\,U^6 - 0.04367\,U^4V^2 - 0.56953\,UV^5 - 0.16240\,U^3V^4 - 0.00776\,U^8 + 0.00726\,U^7V - 0.00485\,U^8V^2 + 0.04105\,U^4V^6 + 0.05398\,UV^9$$

$$\Delta\lambda'' = -1.01486 + 0.14107\,U + 0.85408\,V + 0.21169\,U^2 + 0.25056\,UV - 0.10768\,V^2 + 0.46444\,U^3 - 0.31266\,U^2V - 0.20193\,UV^2 + 0.18042\,U^2V^2 + 0.11677\,V^4 - 0.12972\,U^5 + 0.11348\,U^4V - 0.02386\,U^3V^2 - 0.15945\,V^5 - 0.01031\,U^6V + 0.05005\,UV^6 - 0.02366\,U^4V^4 + 0.00192\,U^9$$

$$\Delta H_m = 13.579 - 11.898\,U + 2.606\,U^2 - 4.757\,UV + 6.771\,V^2 - 1.794\,V^3 - 7.273\,U^2V^2 + 4.633\,UV^3 - 5.660\,V^4 + 1.941\,U^3V^2 - 0.944\,U^2V^3 + 4.462\,UV^4 - 0.009\,U^9$$

In the preceding equations:

$U = K\,(\phi + 22)$
$V = K\,(\lambda - 27)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 62, 64, and 66 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.6 m; λ: ±1.3 m; H (geodetic height): ±1.5 m.

Test Case:

Input data for Arc Datum 1950 test point:	ϕ = -21°09'03.500"S	$\Delta\phi$ = -3.097"
	λ = 27°30'38.724"E	$\Delta\lambda$ = -0.921"
		ΔH = 12.03 m

* Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, Zimbabwe

[Revised: 30 September 1988]

Table 20.3

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Arc Datum 1960* to WGS 84 -

$$\Delta\phi'' = -8.75971 - 2.42934\,U - 0.47525\,V - 1.70734\,U^2 - 0.21247\,V^2 + 0.94299\,U^3 - 4.82318\,U^4 - 0.48322\,U^3V + 2.24563\,U^2V^2 + 10.41787\,UV^3 + 19.09009\,U^6 - 11.89529\,U^2V^5 - 14.08796\,U^8 + 19.61428\,UV^8 - 55.57920\,UV^9 + 12.62838\,U^9V^2 - 189.54308\,U^7V^4 - 82.59136\,U^9V^3 + 413.75352\,U^9V^4$$

$$\Delta\lambda'' = 2.88994 + 0.23890\,U + 0.74278\,V - 0.59971\,U^2 - 0.59553\,UV + 0.76985\,U^2V + 1.08910\,UV^2 + 1.11164\,V^3 - 2.76334\,U^4V - 1.58354\,U^6 + 4.50776\,U^4V^2 - 4.69780\,UV^5 - 0.78364\,V^6 + 2.39396\,U^8 - 18.34020\,V^9$$

$$\Delta H_m = -4.706 - 48.308\,U + 15.189\,V - 41.560\,U^2 + 10.967\,UV - 4.423\,V^2 + 21.834\,U^3 + 140.872\,UV^2 + 14.126\,U^5 - 817.014\,U^2V^3 - 263.676\,UV^4 + 41.387\,U^6 + 517.996\,U^4V^2 + 2398.411\,U^2V^5 + 271.110\,U^7V^2 - 2705.340\,U^3V^6 - 972.194\,U^7V^3 - 5016.963\,U^8V^4 + 21175.898\,U^8V^7$$

In the preceding equations:

$U = K\,(\phi + 3)$
$V = K\,(\lambda - 36)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 38, 41, and 41 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.4 m; λ: ±1.4 m; H (geodetic height): ±1.0 m.

Test Case:

Input data for Arc Datum 1960 test point:	ϕ = -6°03'32.760"S	$\Delta\phi$ = -8.216"
	λ = 35°55'19.249"E	$\Delta\lambda$ = 2.742"
		ΔH = 5.69 m

* Kenya, Tanzania

Table 20.4

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Bellevue (IGN) Datum* to WGS 84 -

$$\Delta\phi'' = 16.12246 - 0.03550\ V^6$$

$$\Delta\lambda'' = 26.36897 - 26.40849\ U^9V^9$$

$$\Delta H_m = 68.606 - 10.688\ U^5V^3$$

In the preceding equations:

$U = K\ (\phi + 18)$
$V = K\ (\lambda - 169)$
$K = 1.57079631$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 3 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.0 m; λ: ±0.2 m; H (geodetic height): ±0.1 m.

Test Case:

Input data for Bellevue (IGN) Datum test point:	ϕ = -17°44'17.400"S	$\Delta\phi$ = 16.079"
	λ = 168°20'33.250"E	$\Delta\lambda$ = 26.381"
		ΔH = 68.74 m

* Efate and Erromango Islands (New Hebrides Islands)

[Revised: 30 September 1988]

Table 20.5

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Bermuda Datum 1957* to WGS 84 -

$$\Delta\phi'' = 6.29809 - 2.78250\ U + 1.42629\ U^2 - 0.00394\ U^9$$

$$\Delta\lambda'' = 0.92185 - 0.76776\ V + 1.65926\ V^2 - 0.81073\ V^3 + 0.00367\ V^9$$

$$\Delta H_m = -30.797 - 1.853\ U + 145.113\ V - 336.079\ V^2 + 181.174\ V^3 + 0.012\ U^9 - 1.008\ V^9 + 0.003\ U^8V^9 - 0.002\ U^9V^9$$

In the preceding equations:

$U = K\ (\phi - 32)$
$V = K\ (\lambda - 295)$
$K = 3.66519141$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 11 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.4 m; λ: ±0.3 m; H (geodetic height): ±0.3 m.

Test Case:

Input data for Bermuda Datum 1957 test point:	ϕ = 32°21'08.707"N	$\Delta\phi$ = 5.044"
	λ = 295°20'37.053"E	$\Delta\lambda$ = 0.996"
		ΔH = -29.44 m

* Bermuda Islands

Table 20.6

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Bogota Observatory Datum* to WGS 84 -

$$\Delta\phi'' = -10.20547 - 0.04536\,U - 0.32067\,V + 0.28431\,UV + 0.16880\,U^2V + 0.90592\,UV^2 + 0.61577\,V^3 - 2.32975\,UV^3 - 0.25607\,V^4 + 2.13800\,U^2V^4 - 4.60849\,U^2V^5$$

$$\Delta\lambda'' = 12.33779 - 0.10858\,U + 0.54020\,V + 0.15784\,U^2 - 1.29192\,V^2 + 0.21029\,U^3 - 0.53682\,V^3 + 2.18555\,V^4 + 0.46590\,U^2V^3 - 0.75178\,V^5 + 5.08165\,UV^6 + 7.79816\,U^2V^8$$

$$\Delta H_m = 10.043 - 43.824\,U + 19.329\,V + 14.074\,UV + 71.105\,V^2 + 36.197\,U^3 - 48.258\,U^2V + 170.437\,V^3 - 39.291\,U^3V - 525.555\,V^4 - 8.762\,U^5 + 145.878\,U^2V^3 - 503.109\,V^5 + 810.751\,V^6 + 1013.581\,U^3V^8$$

In the preceding equations:

$U = K\,(\phi - 6)$
$V = K\,(\lambda - 286)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 22 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.3 m; λ: ±1.4 m; H (geodetic height): ±0.8 m

Test Case:

Input data for Bogota Observatory Datum test point:	ϕ = 2°34'26.221"N	$\Delta\phi$ = -10.276"
	λ = 287°21'36.733"E	$\Delta\lambda$ = 12.466"
		ΔH = 33.29 m

* Colombia

Table 20.7

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Campo Inchauspe Datum* to WGS 84 -

$$\Delta\phi'' = 1.67470 + 0.52924\,U - 0.17100\,V + 0.18962\,U^2 + 0.04216\,UV + 0.19709\,UV^2 - 0.22037\,U^4 - 0.15483\,U^2V^2 - 0.24506\,UV^4 - 0.05675\,V^5 + 0.06674\,U^6 + 0.01701\,UV^5 - 0.00202\,U^7 + 0.08625\,V^7 - 0.00628\,U^8 + 0.00172\,U^8V^4 + 0.00036\,U^9V^6$$

$$\Delta\lambda'' = -2.93117 + 0.18225\,U + 0.69396\,V - 0.04403\,U^2 + 0.07955\,V^2 + 1.48605\,V^3 - 0.00499\,U^4 - 0.02180\,U^4V - 0.29575\,U^2V^3 + 0.20377\,UV^4 - 2.47151\,V^5 + 0.09073\,U^3V^4 + 1.33556\,V^7 + 0.01575\,U^3V^5 - 0.26842\,V^9$$

$$\Delta H_m = 17.004 + 8.380\,U - 7.968\,V + 1.795\,UV - 2.289\,U^3 + 6.660\,U^2V - 3.283\,UV^2 + 3.235\,V^3 + 0.418\,U^4 - 2.475\,U^3V - 4.829\,U^2V^3 + 0.010\,U^7 + 0.011\,U^2V^5 + 0.602\,U^4V^4 + 2.724\,U^2V^7 + 0.215\,U^4V^7 - 1.159\,U^2V^9$$

In the preceding equations:

$U = K\,(\phi + 35)$
$V = K\,(\lambda - 296)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 44 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±1.1 m; H (geodetic height): ±0.8 m

Test Case:

Input data for Campo Inchauspe Datum test point:	ϕ =	-29°47'45.682"S	$\Delta\phi$ =	1.953"
	λ =	301°52'21.803"E	$\Delta\lambda$ =	-1.963"
			ΔH =	18.29 m

* Argentina

Table 20.8

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Canton Astro Datum 1966* to WGS 84 -

$$\Delta\phi'' = -12.36756 + 0.35103\ U^2V^6$$

$$\Delta\lambda'' = 11.07250 + 0.11654\ V$$

$$\Delta H_m = 17.689 - 4.578\ U - 3.911\ UV^7$$

In the preceding equations:

$U = K\ (\phi + 3)$
$V = K\ (\lambda - 188)$
$K = 1.57079631$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 4 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.3 m; λ: ±0.1 m; H (geodetic height): ±0.0 m

Test Case:

Input data for Canton Astro Datum 1966 test point:	ϕ =	-4°29'08.524"S	$\Delta\phi$ =	-12.367"
	λ =	187°49'32.444"E	$\Delta\lambda$ =	11.041"
			ΔH =	28.37 m

* Phoenix Islands

Table 20.9

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Cape Datum* to WGS 84 -

$$\Delta\phi'' = -1.47191 - 0.82976\,U - 0.77153\,V - 1.08380\,U^3 + 0.69870\,UV^2 + 0.85794\,V^3 - 8.05489\,U^5 - 6.08125\,U^6 + 0.44971\,V^6 - 16.35098\,U^5V^2 + 101.23469\,U^8V$$

$$\Delta\lambda'' = -1.41127 + 0.35645\,U + 0.77969\,V + 0.48733\,V^2 - 0.41143\,U^2V - 2.36026\,U^2V^2 + 4.00369\,U^5 - 5.59891\,U^4V + 21.62355\,U^8 - 114.94636\,U^5V^3 + 1521.92420\,U^8V^6$$

$$\Delta H_m = 23.339 - 3.590\,U - 4.129\,V - 10.628\,U^3 - 2.554\,U^2V + 3.724\,V^3 - 21.394\,U^4 + 1.696\,V^6 + 2610.177\,U^9V^5$$

In the preceding equations:

$U = K\,(\phi + 28)$
$V = K\,(\lambda - 26)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 20 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.8 m; λ: ±0.7 m; H (geodetic height): ±0.2 m

Test Case:

Input data for Cape Datum test point:	ϕ =	-22°15'13.678"S	$\Delta\phi$ =	-2.874"
	λ =	29°09'47.488"E	$\Delta\lambda$ =	-0.879"
			ΔH =	14.63 m

* South Africa

Table 20.10

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Cape Canaveral Datum* to WGS 84 -

$$\Delta\phi'' = 1.16421 - 1.08512\ U + 0.13663\ V + 4.91857\ UV^2 + 3.12400\ V^3 + 124.43651\ U^5 - 387.46848\ V^9$$

$$\Delta\lambda'' = 0.86515 - 0.20467\ U + 0.40432\ V + 1.21195\ V^2 - 317.68323\ V^9$$

$$\Delta H_m = -29.579 + 3.968\ U - 74.289\ UV^2 + 74.086\ V^4 + 39588.838\ UV^9$$

In the preceding equations:

$U = K\ (\phi - 27)$
$V = K\ (\lambda - 280)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 27 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.8 m; λ: ±0.9 m; H (geodetic height): ±0.8 m

Test Case:

Input data for Cape Canaveral Datum test point:	ϕ =	26°03'36.424"N	$\Delta\phi$ =	1.268"
	λ =	279°51'51.267"E	$\Delta\lambda$ =	0.880"
			ΔH =	-29.97 m

* Florida and the Bahama Islands

Table 20.11

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Carthage Datum* to WGS 84 -

$$\Delta\phi'' = 5.62302 + 0.97026\ V - 0.30964\ U^2 - 4.50523\ UV - 0.45229\ U^3 - 1.72821\ U^2V - 8.79206\ V^3 + 11.31713\ U^3V + 7.11384\ U^4V - 19.74569\ UV^4 + 38.84103\ U^2V^4 + 95.47870\ UV^5 + 282.34348\ V^9$$

$$\Delta\lambda'' = 1.75559 + 0.96288\ U + 0.46232\ V + 0.98581\ U^2 + 0.23217\ UV + 1.72414\ V^2 - 2.04345\ U^3 - 2.05410\ U^4 + 18.63465\ U^5V^3 - 122.61534\ V^8$$

$$\Delta H_m = 31.477 + 10.815\ U + 2.921\ V + 12.107\ U^2 + 7.567\ V^2 - 18.692\ U^3 - 20.265\ U^4 + 74.574\ UV^3 - 2077.760\ UV^8$$

In the preceding equations:

$U = K\ (\phi - 35)$
$V = K\ (\lambda - 9)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 21 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.9 m; λ: ±1.2 m; H (geodetic height): ±0.6 m

Test Case:

Input data for Carthage Datum test point:	ϕ =	36°49'21.208"N	$\Delta\phi$ =	5.280"
	λ =	10°46'08.814"E	$\Delta\lambda$ =	2.514"
			ΔH =	39.19 m

* Tunisia

Table 20.12

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Chatham Datum 1971* to WGS 84 -

$$\Delta\phi'' = 1.70498 + 2115.19930\ V^5$$

$$\Delta\lambda'' = 2.11344 + 0.92449\ V$$

$$\Delta H_m = 6.412 - 25.629\ V$$

In the preceding equations:

$U = K\ (\phi + 44)$
$V = K\ (\lambda - 183)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 4 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.1 m; λ: ±0.6 m; H (geodetic height): ±0.3 m

Test Case:

Input data for Chatham Datum 1971 test point:	ϕ =	-43°47'29.102"S	$\Delta\phi$ =	1.705"
	λ =	183°10'33.902"E	$\Delta\lambda$ =	2.139"
			ΔH =	5.70 m

* Chatham Island

Table 20.13

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Chua Astro Datum* to WGS 84 -

$$\Delta\phi'' = -2.21781 + 0.54448\,U - 0.16463\,V - 0.47450\,U^2 - 0.49228\,UV - 9.12731\,U^3V^6$$

$$\Delta\lambda'' = 0.28682 + 0.70405\,V - 2.88525\,UV - 4.82907\,UV^2 + 39.41621\,UV^3 + 2.93416\,V^4 - 92.33439\,UV^5 - 0.49038\,U^7 + 180.05225\,U^2V^9 - 125.64645\,U^8V^5$$

$$\Delta H_m = 9.322 + 6.031\,U + 0.414\,V - 37.127\,U^2 - 30.453\,UV - 10.042\,V^2 + 76.251\,U^2V + 4.806\,V^3 + 35.515\,U^4 + 89.644\,U^2V^2 + 3.270\,V^5$$

In the preceding equations:

$U = K\,(\phi + 25)$
$V = K\,(\lambda - 302)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 18 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.3 m; λ: ±0.5 m; H (geodetic height): ±0.8 m

Test Case:

Input data for Chua Astro Datum test point:	ϕ =	-25°19'23.270"S	$\Delta\phi$ =	-2.322"
	λ =	305°24'47.315"E	$\Delta\lambda$ =	0.957"
			ΔH =	8.14 m

* Paraguay

Table 20.14

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Corrego Alegre Datum* to WGS 84 -

$$\Delta\phi'' = -0.84315 + 0.74089\,U - 0.21968\,V - 0.98875\,U^2 + 0.89883\,UV + 0.42853\,U^3 + 2.73442\,U^4 - 0.34750\,U^3V + 4.69235\,U^2V^3 - 1.87277\,U^6 + 11.06672\,U^5V - 46.24841\,U^3V^3 - 0.92268\,U^7 - 14.26289\,U^7V + 334.33740\,U^5V^5 - 15.68277\,U^9V^2 - 2428.85860\,U^8V^8$$

$$\Delta\lambda'' = -1.46053 + 0.63715\,U + 2.24996\,V - 5.66052\,UV + 2.22589\,V^2 - 0.34504\,U^3 - 8.54151\,U^2V + 0.87138\,U^4 + 43.40004\,U^3V + 4.35977\,UV^3 + 8.17101\,U^4V + 16.24298\,U^2V^3 + 19.96900\,UV^4 - 8.75655\,V^5 - 125.35753\,U^5V - 127.41019\,U^3V^4 - 0.61047\,U^8 + 138.76072\,U^7V + 122.04261\,U^5V^4 - 51.86666\,U^9V + 45.67574\,U^9V^3$$

$$\Delta H_m = -8.765 - 9.454\,U - 7.325\,V + 21.798\,U^2V + 17.921\,UV^2 - 2.168\,U^4 - 34.514\,U^2V^2 + 5.573\,U^5 - 18.770\,U^4V + 90.838\,U^8V^2$$

In the preceding equations:

$U = K\,(\phi + 15)$
$V = K\,(\lambda - 310)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 46, 45, and 47 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.1 m; λ: ±1.2 m; H (geodetic height): ±0.7 m

Test Case:

Input data for Corrego Alegre Datum test point:	ϕ =	-20°29'01.019"S	$\Delta\phi$ =	-1.030"
	λ =	305°12'46.829"E	$\Delta\lambda$ =	-2.101"
			ΔH =	-5.16 m

* Brazil

Table 20.15

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Djakarta Datum* to WGS 84 -

$$\Delta\phi'' = -1.66114 - 2.10884\,U + 0.20931\,V + 0.54056\,UV + 1.43422\,U^3 + 1.35169\,U^2V + 0.47553\,U^4V + 1.89489\,U^2V^4 + 0.41506\,U^9 - 3.02864\,U^4V^9$$

$$\Delta\lambda'' = 8.15798 + 0.52103\,U - 0.20776\,V + 0.49247\,U^2 + 0.31892\,U^3 - 1.26810\,U^2V - 0.74453\,V^3 + 0.94524\,U^5 - 2.42459\,U^6 - 1.51501\,U^7V + 4.34916\,U^6V^9$$

$$\Delta H_m = -5.198 - 12.267\,U + 2.855\,V - 12.562\,U^2 + 18.596\,U^2V + 6.077\,V^3 + 19.700\,U^4 + 9.834\,U^8V - 52.945\,U^6V^8$$

In the preceding equations:

$U = K\,(\phi - 0)$
$V = K\,(\lambda - 100)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 17, 18, and 18 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.1 m; λ: ±1.0 m; H (geodetic height): ±0.6 m

Test Case:

Input data for Djakarta Datum test point:	ϕ =	5°25'51.475"N	$\Delta\phi$ =	-3.409"
	λ =	95°32'32.178"E	$\Delta\lambda$ =	9.980"
			ΔH =	-31.04 m

* Sumatra

Table 20.16

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- ED 50 (Cyprus) to WGS 84 -

$$\Delta\phi'' = -3.84288 + 0.09188\,U + 0.03581\,V - 0.07481\,UV$$

$$\Delta\lambda'' = -1.10294 - 0.04240\,U + 0.12748\,V - 0.32783\,UV^2 + 0.51023\,UV^3 - 0.01600\,V^7 - 0.1718\,U^3V^9$$

$$\Delta H_m = 24.430 - 5.719\,U + 0.0778\,V + 5.631\,U^2 - 23.892\,UV + 18.980\,U^2V - 0.988\,V^3 + 106.027\,U^3V - 42.824\,U^4V - 323.655\,U^9V^2 + 2.261\,U^4V^9$$

<u>In the preceding equations</u>:

$U = K\,(\phi - 35)$
$V = K\,(\lambda - 33)$
$K = 0.78539816$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 16 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.5 m; λ: ±0.3 m; H (geodetic height): ±0.2 m

<u>Test Case</u>:

Input data for ED 50 (Cyprus) test point:	ϕ =	34°43'23.316"N	$\Delta\phi$ =	-3.885"
	λ =	32°28'06.026"E	$\Delta\lambda$ =	-1.126"
			ΔH =	23.64 m

Table 20.17

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- ED 50 (Egypt) to WGS 84 -

$$\Delta\phi'' = -4.26321 + 0.53413\,U - 0.25545\,V + 0.22185\,U^2 - 0.94305\,UV + 0.32199\,V^2 + 1.45564\,U^3V - 5.32845\,U^7 - 27.06979\,U^3V^4 - 17.61168\,U^4V^4 + 50.14314\,U^5V^4$$

$$\Delta\lambda'' = -1.43240 + 2.03143\,V + 0.83784\,U^2 - 0.18148\,UV + 2.45164\,V^2 - 2.19685\,U^2V - 17.28492\,V^3 - 18.37881\,U^2V^2 - 4.37317\,V^4 + 58.86054\,V^5 + 37.96406\,U^2V^4 + 16.79416\,U^4V^3 - 64.07183\,V^7 + 67.58848\,U^8V^2$$

$$\Delta H_m = 7.841 - 8.571\,U + 6.308\,V + 9.597\,U^2 - 48.792\,UV + 12.857\,V^2 - 35.858\,U^3 + 19.847\,U^2V - 19.243\,V^3 - 32.325\,V^4 + 132.326\,U^5 + 335.520\,U^5V + 1620.894\,UV^9 - 3902.371\,U^3V^9$$

In the preceding equations:

$U = K\,(\phi - 27)$
$V = K\,(\lambda - 30)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 30 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±1.4 m; H (geodetic height): ±1.1 m

Test Case:

Input data for ED 50 (Egypt) test point:	ϕ =	29°50'07.103"N	$\Delta\phi$ =	-4.116"
	λ =	30°36'05.306"E	$\Delta\lambda$ =	-1.247"
			ΔH =	5.20 m

Table 20.18

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- ED 50 (Iran) to WGS 84 -

$$\Delta\phi'' = -4.14386 + 0.35424\,U + 0.09268\,UV + 0.74969\,U^3 - 0.28888\,V^3 + 0.10130\,UV^3 - 0.84113\,U^5 - 0.11329\,U^4V + 0.08632\,V^5 - 0.18535\,U^3V^3 + 0.18609\,U^7 + 0.22312\,U^2V^5 - 0.05310\,UV^7 + 0.05686\,U^3V^8 + 0.02849\,U^3V^9$$

$$\Delta\lambda'' = 0.12417 + 0.43410\,U + 0.65033\,V + 3.66512\,U^2 + 0.26615\,UV + 0.34660\,V^2 - 0.79178\,U^3 - 1.13677\,U^2V - 0.70829\,UV^2 - 7.82858\,U^4 - 0.20007\,UV^3 - 0.12099\,V^4 + 3.67528\,U^4V + 2.06675\,U^3V^2 + 7.24212\,U^6 + 0.61665\,U^5V - 0.75923\,U^3V^3 - 0.75831\,U^2V^4 + 0.19255\,U^7 - 3.20687\,U^6V + 0.08964\,UV^6 - 2.27832\,U^8 - 0.00669\,U^4V^4 - 1.78975\,U^7V^2 - 0.26966\,U^9V^3$$

$$\Delta H_m = -5.287 - 19.726\,U + 3.664\,V + 13.034\,UV + 24.858\,U^3 - 5.856\,U^2V - 12.079\,U^4 - 18.577\,U^2V^2 - 3.275\,UV^3 - 15.804\,U^5 + 8.058\,U^3V^2 - 1.694\,V^5 + 10.972\,U^6 + 10.770\,U^2V^4 - 0.462\,V^8 - 3.976\,U^3V^6 - 0.358\,U^3V^9$$

In the preceding equations:

$U = K\,(\phi - 32)$
$V = K\,(\lambda - 55)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 47 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±1.4 m; H (geodetic height): ±1.6 m

Test Case:

Input data for ED 50 (Iran) test point:	ϕ =	29°28'59.127"N	$\Delta\phi$ =	-4.518"
	λ =	60°52'31.547"E	$\Delta\lambda$ =	1.145"
			ΔH =	-3.22 m

Table 20.19

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Geodetic Datum 1949* to WGS 84 -

$$\Delta\phi'' = 6.18012 + 0.18236\,U + 0.10785\,V - 0.15566\,UV + 1.36545\,U^3 - 0.44813\,UV^2 + 0.16518\,V^3 - 1.66408\,U^5 + 0.44854\,U^9$$

$$\Delta\lambda'' = 0.55131 + 0.18193\,U + 0.29501\,V - 0.36522\,UV - 0.12613\,U^3 - 1.13550\,U^2V^2 + 3.31705\,U^3V^3 + 3.40098\,U^9V^6$$

$$\Delta H_m = 8.630 + 13.910\,U + 7.007\,V + 3.463\,V^2 + 20.507\,U^3 - 16.813\,U^2V - 20.530\,U^6V - 11.602\,U^9 - 28.424\,U^9V^3$$

In the preceding equations:

$U = K\,(\phi + 41)$
$V = K\,(\lambda - 173)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 31 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.9 m; λ: ±0.7 m; H (geodetic height): ±1.2 m

Test Case:

Input data for Geodetic Datum 1949 test point:	ϕ =	-41°17'32.050"S	$\Delta\phi$ =	6.176"
	λ =	173°15'15.405"E	$\Delta\lambda$ =	0.555"
			ΔH =	8.27 m

* New Zealand

Table 20.20

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Guam Datum 1963* to WGS 84 -

$$\Delta\phi'' = 5.17587 + 0.22868\ UV^4 - 0.47793\ U^4V^5 + 0.00015\ V^9 - 0.07930\ U^5V^7 + 0.38348\ U^8V^8 + 0.14079\ U^9V^9$$

$$\Delta\lambda'' = 8.74222 - 3.34020\ U + 8.74187\ U^2 - 6.34324\ U^3 + 0.85495\ U^5$$

$$\Delta H_m = 52.110 + 5.279\ V - 0.855\ V^3 + 0.114\ UV^7 - 0.023\ U^2V^9$$

<u>In the preceding equations</u>:

$U = K\ (\phi - 13)$
$V = K\ (\lambda - 144)$
$K = 1.57079631$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 11 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.8 m; λ: ±0.4 m; H (geodetic height): ±1.2 m

<u>Test Case</u>:

Input data for Guam Datum 1963 test point:	ϕ = 13°36'56.376"N	$\Delta\phi$ = 5.171"
	λ = 144°51'25.420"E	$\Delta\lambda$ = 8.674"
		ΔH = 57.70 m

* Guam Island

Table 20.21

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Hjorsey Datum 1955* to WGS 84 -

$$\Delta\phi'' = -1.10314 + 0.50569\,U + 0.61317\,U^2 - 7.18436\,U^5 - 23.54798\,U^9V - 0.13673\,U^2V^8$$

$$\Delta\lambda'' = 1.41076 + 0.72408\,V + 1.34450\,U^2 - 0.28168\,V^3 - 12.78896\,U^6 - 10.20299\,U^6V^3$$

$$\Delta H_m = 61.924 - 5.697\,U + 63.712\,U^2 - 8.224\,UV - 1.524\,V^2 + 144.810\,U^3 - 420.492\,U^4 + 87.768\,U^4V^5$$

In the preceding equations:

$U = K\,(\phi - 64)$
$V = K\,(\lambda - 341)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 19 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±0.9 m; H (geodetic height): ±1.0 m

Test Case:

Input data for Hjorsey Datum 1955 test point:	ϕ =	64°31'29.258"N	$\Delta\phi$ =	-1.040"
	λ =	337°37'54.160"E	$\Delta\lambda$ =	1.015"
			ΔH =	62.08 m

* Iceland

Table 20.22

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Indian Datum* to WGS 84 -

$$\Delta\phi'' = 6.30669 - 0.41180\,U + 0.45552\,V - 0.96595\,U^2 + 0.31697\,UV - 0.48167\,V^2 - 0.09791\,U^3 - 6.60932\,V^3 + 0.40350\,U^4 - 0.14233\,U^3V + 0.60845\,U^3V^2 + 19.25057\,V^5 + 0.05826\,U^7 - 0.82453\,U^5V^2 + 1.51908\,U^4V^3 - 19.45903\,V^7 - 0.45581\,U^5V^3 + 2.02975\,U^4V^4 + 6.24026\,V^9 + 0.26237\,U^6V^7$$

$$\Delta\lambda'' = -12.88589 - 0.80318\,U - 1.64008\,V - 0.16164\,U^2 - 1.58754\,UV + 2.00136\,V^2 + 0.57130\,U^3 + 0.62091\,U^3V - 10.96520\,V^4 - 0.13892\,U^5 + 0.09699\,U^4V + 0.25365\,V^5 + 0.24101\,U^5V + 0.57246\,U^4V^2 + 0.54428\,UV^5 + 11.95528\,V^6 + 0.51469\,U^3V^4 - 3.80343\,V^8 + 0.16968\,U^6V^3 + 0.07936\,U^9V^2 + 0.05200\,U^9V^5$$

$$\Delta H_m = -29.391 - 15.922\,V + 14.787\,U^2 - 13.320\,UV + 1.015\,U^3 + 2.266\,UV^2 - 8.544\,V^3 - 13.228\,U^4 - 6.601\,V^4 - 14.879\,U^2V^3 + 4.036\,U^6 + 1.916\,U^5V + 11.199\,U^4V^3 + 6.068\,V^7 + 3.470\,U^4V^4$$

In the preceding equations:

$U = K\,(\phi - 13)$
$V = K\,(\lambda - 103)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 38, 40, and 39 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.6 m; λ: ±1.4 m; H (geodetic height): ±1.3 m

Test Case:

Input data for Indian Datum test point:	ϕ = 16°32'45.140"N	$\Delta\phi$ = 6.209"
	λ = 107°38'49.803"E	$\Delta\lambda$ = -15.664"
		ΔH = -59.53 m

* Thailand and Vietnam only. Contact DMA (see PREFACE) if data in this form is needed for Bangladesh, India, and Nepal

Table 20.23

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Ireland Datum 1965* to WGS 84 -

$$\Delta\phi'' = 1.01297 - 1.55326\,U - 0.83565\,U^2 + 3.45237\,UV + 10.42033\,U^3 - 4.52518\,UV^3 + 1260.47570\,U^8V^4$$

$$\Delta\lambda'' = -3.62716 + 1.11402\,V + 1.73255\,U^2 + 32.41814\,V^2 - 9.39322\,U^2V - 0.66537\,UV^2 + 102.63359\,V^3 + 132.39954\,V^4 + 210.32656\,U^4V + 61.75430\,V^5 + 1116.76600\,U^8 + 939.22583\,U^6V^2 + 767.75304\,U^6V^7$$

$$\Delta H_m = 51.881 + 1.772\,U - 2.238\,V + 2.177\,UV + 1.410\,V^5$$

In the preceding equations:

$U = K\,(\phi - 53)$
$V = K\,(\lambda - 354)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 22, 21, and 22 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.4 m; λ: ±0.6 m; H (geodetic height): ±0.3 m

Test Case:

Input data for Ireland Datum 1965 test point:	ϕ =	54°22'26.715"N	$\Delta\phi$ =	0.415"
	λ =	351°37'44.633"E	$\Delta\lambda$ =	-2.621"
			ΔH =	53.15 m

* Ireland

Table 20.24

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Kandawala Datum* to WGS 84 -

$$\Delta\phi'' = 1.21983 - 0.45486\ U - 0.07532\ V^2 + 0.05193\ V^6$$

$$\Delta\lambda'' = 7.57891 + 0.07158\ U - 0.84390\ V - 0.03457\ U^2 - 0.09152\ UV^2 + 0.01253\ U^9V$$

$$\Delta H_m = -\ 94.499 + 1.087\ U + 7.514\ V - 0.094\ U^2 + 0.956\ UV^2 - 0.272\ U^2V^2 - 42.147\ UV^8 - 0.177V^9 + 49.565\ UV^9$$

In the preceding equations:

$U = K\ (\phi - 7)$
$V = K\ (\lambda - 80)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 17 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.8 m; λ: ±0.7 m; H (geodetic height): ±0.1 m

Test Case:

Input data for Kandawala Datum test point:	ϕ =	7°37'02.730"N	$\Delta\phi$ =	1.039"
	λ =	81°40'49.750"E	$\Delta\lambda$ =	6.833"
			ΔH =	-87.21 m

* Sri Lanka

Table 20.25

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Kertau Datum 1948* to WGS 84 -

$$\Delta\phi'' = -0.72690 - 0.41117\,U + 0.15112\,V + 0.12332\,V^2 - 0.05560\,U^3 - 0.00966\,U^9V - 0.60881\,U^4V^9 + 0.97603\,U^5V^9$$

$$\Delta\lambda'' = -5.42037 + 0.14298\,U - 1.17613\,V - 0.20661\,U^2 + 1.27718\,V^3 + 0.42230\,U^4V + 0.63147\,U^3V^2 - 0.20582\,U^5V - 0.69876\,U^2V^5 - 0.54175\,V^8 - 0.64231\,UV^9 + 0.82187\,U^4V^9$$

$$\Delta H_m = 1.527 - 3.043\,V - 4.561\,U^2 + 2.444\,U^3 + 1.298\,U^3V^2 + 12.411\,U^6V^8$$

In the preceding equations:

$U = K\,(\phi - 3)$
$V = K\,(\lambda - 102)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 18 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.0 m; λ: ±1.0 m; H (geodetic height): ±0.9 m

Test Case:

Input data for Kertau Datum 1948 test point:	ϕ =	3°27'50.710"N	$\Delta\phi$ =	-0.759"
	λ =	102°37'24.550"E	$\Delta\lambda$ =	-5.684"
			ΔH =	0.58 m

* West Malaysia and Singapore

Table 20.26

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Liberia Datum 1964* to WGS 84 -

$$\Delta\phi'' = 0.51236 - 0.50199\ U + 0.19599\ U^2 - 0.78118\ U^4 - 1.40415\ U^5 + 1.14578\ U^7 + 0.48817\ U^8$$

$$\Delta\lambda'' = 0.83381 + 0.12109\ V - 1.15747\ U^2 + 4.17464\ U^4 - 2.87835\ U^6 - 0.00347\ V^6 + 0.75462\ U^7 - 0.66246\ U^9$$

$$\Delta H_m = 22.686 + 1.214\ U^3 + 0.730\ V^3 + 2.651\ U^4 - 2.772\ U^6 - 0.041\ V^8 - 0.497\ U^9$$

In the preceding equations:

$U = K\ (\phi - 7)$
$V = K\ (\lambda - 350)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 20 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.5 m; λ: ±1.2 m; H (geodetic height): ±0.4 m

Test Case:

Input data for Liberia Datum 1964 test point:	ϕ =	7°31'11.956"N	$\Delta\phi$ =	0.384"
	λ =	351°28'54.245"E	$\Delta\lambda$ =	0.863"
			ΔH =	23.06 m

* Liberia

Table 20.27

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Luzon Datum* to WGS 84 -

$$\Delta\phi'' = -4.81355 - 0.59913\,U - 0.09937\,V - 0.51911\,U^2 + 0.28771\,V^2 + 0.44253\,U^2V + 0.22569\,U^4 + 0.47409\,UV^4 - 0.89246\,U^5V^2 - 0.70372\,U^6V^2 + 0.00860\,U^9$$

$$\Delta\lambda'' = 5.10770 - 0.29185\,U + 0.04185\,V + 0.48103\,V^2 + 0.23972\,U^3 - 0.12251\,U^3V - 2.57709\,U^2V^2 + 14.91383\,U^4V^4 + 17.78653\,U^3V^5 - 0.00540\,U^9 - 9.52315\,U^3V^7 - 4.72388\,U^6V^5$$

$$\Delta H_m = 51.075 + 6.883\,V - 0.885\,U^2 - 42.832\,UV - 0.681\,V^2 - 15.610\,U^3 + 45.350\,U^3V + 108.705\,UV^3 + 5.666\,U^5 - 4.855\,U^3V^2 - 65.708\,UV^4 - 12.935\,U^5V + 896.300\,U^2V^8 - 836.997\,U^2V^9$$

In the preceding equations:

$U = K\,(\phi - 12)$
$V = K\,(\lambda - 122)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 24, 26, and 26 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.1 m; λ: ±1.3 m; H (geodetic height): ±1.3 m

Test Case:

Input data for Luzon Datum test point:	ϕ =	6°06'29.040"N	$\Delta\phi$ =	-3.973"
	λ =	125°10'44.230"E	$\Delta\lambda$ =	4.986"
			ΔH =	70.55 m

* The Philippines (Except Mindanao Island)

Table 20.28

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Merchich Datum* to WGS 84 -

$$\Delta\phi'' = -9.15842 - 0.69580\,U - 0.45597\,V + 0.26095\,UV + 0.09490\,V^3 - 0.21306\,U^2V^2 + 0.26479\,U^8 + 1.37933\,U^8V - 0.58879\,U^7V^2$$

$$\Delta\lambda'' = 5.70056 + 0.19659\,U + 0.05914\,U^2 - 0.09782\,UV - 0.66866\,UV^3 - 0.42469\,U^4V + 0.38831\,UV^5 + 0.10930\,U^9 + 0.84666\,U^5V^7 + 0.67921\,U^6V^7 + 0.14063\,U^4V^9$$

$$\Delta H_m = 47.063 - 7.758\,U + 5.293\,U^2 + 19.518\,UV + 4.735\,U^3 - 10.062\,U^4 - 29.573\,UV^3 - 7.921\,U^3V^2 + 8.701\,UV^5$$

In the preceding equations:

$U = K\,(\phi - 32)$
$V = K\,(\lambda - 353)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 32 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.3 m; λ: ±0.5 m; H (geodetic height): ±1.4 m

Test Case:

Input data for Merchich Datum test point:	ϕ =	35°08'39.942"N	$\Delta\phi$ =	-9.863"
	λ =	357°34'13.307"E	$\Delta\lambda$ =	5.675"
			ΔH =	41.46 m

* Morocco

Table 20.29

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Minna Datum* to WGS 84 -

$$\Delta\phi'' = 0.49461 - 0.69094\,U + 0.39940\,V - 7.44709\,U^3 - 1.82129\,U^2V - 2.92752\,UV^2 + 5.70789\,U^3V - 2.10838\,U^2V^2 - 6.88780\,UV^3 + 14.35602\,U^5 + 5.10389\,UV^4 + 6.18524\,U^6 + 8.62320\,UV^5 + 48.52705\,U^7V^2 - 0.49769\,V^9 - 11.39331\,U^4V^8$$

$$\Delta\lambda'' = -2.624356 - 0.21876\,U + 0.43678\,V + 0.35068\,UV - 1.53864\,U^2V - 0.46268\,UV^3 + 2.20240\,U^4V - 0.11456\,V^5 + 1.59485\,U^3V^4$$

$$\Delta H_m = 20.013 + 2.098\,U - 11.691\,V + 47.983\,U^2V - 60.195\,U^4V - 21.214\,U^2V^3 + 8.642\,V^5 - 12.588\,U^5V - 27.760\,U^2V^8$$

In the preceding equations:

$U = K\,(\phi - 10)$
$V = K\,(\lambda - 8)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 23 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±1.0 m; H (geodetic height): ±0.7 m

Test Case:

Input data for Minna Datum test point:	ϕ =	9°19'09.051"N	$\Delta\phi$ =	0.930"
	λ =	12°13'50.125"E	$\Delta\lambda$ =	-2.348"
			ΔH =	13.43m

* Nigeria

Table 20.30

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Nahrwan Datum* to WGS 84 -

$$\Delta\phi'' = 6.38908 - 0.53788\,U + 0.04816\,U^2 - 0.14476\,U^2V - 0.16987\,V^3 + 0.53171\,U^3V^4 - 0.01410\,U^9 + 0.04281\,V^9 + 0.44507\,U^8V^9$$

$$\Delta\lambda'' = 4.40107 + 0.12321\,U + 0.36418\,V + 0.06577\,UV^3 - 0.10987\,U^3V^2 + 0.27991\,U^2V^5 + 0.04889\,UV^8 - 0.04749\,U^9V^2 + 0.25424\,U^9V^8$$

$$\Delta H_m = -36.488 + 6.910\,U + 4.728\,V + 0.264\,V^2 + 10.160\,U^3 + 0.739\,U^2V - 13.461\,U^5 - 0.170\,U^6 + 3.090\,U^9 - 0.774\,U^8V^9 - 0.473\,U^9V^9$$

In the preceding equations:

$U = K\,(\phi - 23)$
$V = K\,(\lambda - 57)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 20 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.7 m; λ: ±0.3 m; H (geodetic height): ±0.1 m

Test Case:

Input data for Nahrwan Datum test point:	ϕ =	24°58'07.671"N	$\Delta\phi$ =	6.276"
	λ =	55°00'07.720"E	$\Delta\lambda$ =	4.059"
			ΔH =	-33.88 m

* Masirah Island (Oman) and United Arab Emirates only.

Table 20.31

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Alaska) to WGS 84 -

$$\Delta\phi'' = -2.08611 + 0.59833\,U + 0.52967\,V + 0.23473\,U^2 + 0.23563\,UV + 0.28672\,UV^2 + 0.27573\,V^3 + 0.19561\,U^4 - 0.15184\,U^3V - 0.21241\,U^2V^2 + 0.04891\,V^4 - 0.18860\,UV^4 - 17.032\,V^5 - 0.05741\,UV^5 - 0.04292\,U^2V^5 + 0.02097\,V^7 - 0.01487\,U^2V^6 - 0.00384\,V^8 - 0.18402\,U^9 - 0.00188\,U^3V^7$$

$$\Delta\lambda'' = -8.19369 - 1.56665\,U + 0.73861\,V - 3.10809\,U^2 - 0.35323\,UV - 0.06926\,V^2 - 0.68114\,UV^2 - 0.32398\,V^3 + 0.74679\,U^4 + 0.43200\,U^3V + 4.24388\,U^2V^2 + 0.14065\,UV^3 - 0.30990\,U^2V^3 + 0.11365\,V^5 - 1.48566\,U^4V^2 - 1.96501\,U^2V^4 + 2.04229\,U^6V - 0.48255\,U^5V^2 + 0.09847\,UV^6 + 0.49313\,U^2V^6 - 1.00218\,U^8V - 0.02809\,U^2V^8 + 0.00054\,U^5V^9$$

$$\Delta H_m = 8.352 - 13.742\,U - 8.268\,V + 0.900\,V^2 + 5.340\,U^3 + 2.960\,UV^2 - 2.016\,V^3 + 5.087\,U^3V + 1.437\,UV^3 + 0.951\,V^5 - 2.461\,U^3V^4 - 1.560\,U^8 - 1.980\,U^7V - 0.205\,U^5V^3 + 0.094\,UV^8 - 2.885\,U^8V^2 - 0.011\,UV^9$$

<u>In the preceding equations</u>:

$U = K\,(\phi - 62)$
$V = K\,(\lambda - 208)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 85, 86, and 86 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.7 m; λ: ±1.7 m; H (geodetic height): ±1.2 m

<u>Test Case</u>:

Input data for NAD 27 (Alaska) test point:	ϕ =	64°31'09.064"N	$\Delta\phi$ =	-2.648"
	λ =	194°37'28.092"E	$\Delta\lambda$ =	-9.525"
			ΔH =	19.20 m

Table 20.32

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Canada) to WGS 84 -

$$\begin{aligned}\Delta\phi'' = {} & 0.79395 + 2.29199\,U + 0.27589\,V - 1.76644\,U^2 + 0.47743\,UV + 0.08421\,V^2 - 6.03894\,U^3 \\ & - 3.55747\,U^2V - 1.81118\,UV^2 - 0.20307\,V^3 + 7.75815\,U^4 - 3.10170\,U^3V + 3.58363\,U^2V^2 \\ & - 1.31086\,UV^3 - 0.45916\,V^4 + 14.27239\,U^5 + 3.28815\,U^4V + 1.35742\,U^2V^3 + 1.75323\,UV^4 \\ & + 0.44999\,V^5 - 19.02041\,U^4V^2 - 1.01631\,U^2V^4 + 1.47331\,UV^5 + 0.15181\,V^6 + 0.41614\,U^2V^5 \\ & - 0.80920\,UV^6 - 0.18177\,V^7 + 5.19854\,U^4V^4 - 0.48837\,UV^7 - 0.01473\,V^8 - 2.26448\,U^9 \\ & - 0.46457\,U^2V^7 + 0.11259\,UV^8 + 0.02067\,V^9 + 47.64961\,U^8V^2 + 0.04828\,UV^9 + 36.38963\,U^9V^2 \\ & + 0.06991\,U^4V^7 + 0.08456\,U^3V^8 + 0.09113\,U^2V^9 + 5.93797\,U^7V^5 - 2.36261\,U^7V^6 + 0.095775\,U^5V^8\end{aligned}$$

$$\begin{aligned}\Delta\lambda'' = {} & 1.36099 + 3.61796\,V - 3.97703\,U^2 + 3.09705\,UV - 1.15866\,V^2 - 13.28954\,U^3 - 3.15795\,U^2V \\ & + 0.68405\,UV^2 - 0.50303\,V^3 - 8.81200\,U^3V - 2.17587\,U^2V^2 - 1.49513\,UV^3 + 0.84700\,V^4 \\ & + 31.42448\,U^5 - 14.67474\,U^3V^2 + 0.65640\,UV^4 + 17.55842\,U^6 + 6.87058\,U^4V^2 - 0.21565\,V^6 \\ & + 62.18139\,U^5V^2 + 1.78687\,U^3V^4 + 2.74517\,U^2V^5 - 0.30085\,UV^6 + 0.04600\,V^7 + 63.52702\,U^6V^2 \\ & + 7.83682\,U^5V^3 + 9.59444\,U^3V^5 + 0.01480\,V^8 + 10.51228\,U^4V^5 - 1.42398\,U^2V^7 - 0.00834\,V^9 \\ & + 5.23485\,U^7V^3 - 3.18129\,U^3V^7 + 8.45704\,U^9V^2 - 2.29333\,U^4V^7 + 0.14465\,U^2V^9 + 0.29701\,U^3V^9 \\ & + 0.17655\,U^4V^9\end{aligned}$$

$$\begin{aligned}\Delta H_m = {} & -26.806 + 9.266\,U - 5.857\,V + 14.794\,U^2 + 3.497\,UV + 9.600\,V^2 - 7.664\,UV^2 - 40.040\,U^2V^2 \\ & - 3.439\,V^4 + 14.592\,U^2V^3 - 23.902\,U^5V + 15.246\,U^4V^2 + 18.445\,U^2V^4 + 0.770\,V^6 - 130.424\,U^6V \\ & - 11.874\,U^2V^5 - 100.769\,U^7V - 3.165\,U^2V^6 - 0.182\,UV^7 - 0.066\,V^8 + 2.404\,U^2V^7 + 0.073\,UV^8 \\ & - 0.074\,U^2V^9\end{aligned}$$

Table 20.32 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Canada) to WGS 84 -

In the preceding equations:

$U = K(\phi - 60)$
$V = K(\lambda - 260)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 145, 144, and 153 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.5 m; λ: ±1.8 m; H (geodetic height): ±1.6 m

Test Case:

Input data for NAD 27 (Canada) test point:	ϕ =	54°26'08.667"N	$\Delta\phi$ =	0.289"
	λ =	249°42'57.590"E	$\Delta\lambda$ =	-3.156"
			ΔH =	-22.36 m

Table 20.33

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Caribbean*) to WGS 84 -

$$\Delta\phi'' = 2.18504 - 2.43432\,U - 0.43566\,V - 5.51944\,U^2 - 0.27046\,UV + 12.61954\,U^3 - 2.88156\,U^2V + 1.67846\,UV^2 + 0.95009\,V^3 + 31.98970\,U^4 - 13.72449\,U^3V - 6.90489\,U^2V^2 - 0.41847\,V^4 - 47.35821\,U^5 + 6.14556\,U^2V^3 - 43.90069\,U^6 + 74.23430\,U^5V + 7.40175\,U^2V^4 + 0.00881\,V^6 + 42.60766\,U^7 - 4.43185\,U^2V^5 + 18.21904\,U^8 - 77.96877\,U^7V - 0.05853\,UV^7 + 9.22708\,U^8V^2 + 0.09311\,U^3V^7 + 20.04825\,U^9V^2 + 0.06618\,U^4V^9$$

$$\Delta\lambda'' = 0.94649 + 0.14781\,U + 0.62356\,V + 0.07604\,U^2 - 0.64115\,UV - 0.67051\,U^2V + 0.86816\,V^3 + 0.46311\,U^3V + 0.59579\,U^4V - 2.03251\,V^5 + 1.69755\,V^6 - 0.41475\,V^8 + 0.10863\,V^9$$

$$\Delta H_m = -39.801 + 6.864\,U + 2.477\,V + 43.076\,U^2 + 2.867\,V^2 - 171.105\,U^4 + 230.032\,U^6 - 0.058\,V^7 - 95.522\,U^8$$

In the preceding equations:

$U = K\,(\phi - 20)$
$V = K\,(\lambda - 283)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 57 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.8 m; λ: ±2.7 m; H (geodetic height): ±2.6 m

Test Case:

Input data for NAD 27 (Caribbean) test point	ϕ =	21°25'58.442"N	$\Delta\phi$ =	1.637"
	λ =	288°51'14.645"E	$\Delta\lambda$ =	1.393"
			ΔH =	-35.29 m

* Bahama Islands (includes San Salvador Island), Barbados Island, Cuba, Dominican Republic, Grand Cayman Island, Jamaica, Leeward Islands, and Turks and Caicos Islands

[Revised: 30 September 1988]

Table 20.34

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- NAD 27 (Mexico, Central America) to WGS 84 -

$$\Delta\phi'' = 0.67775 + 10.02259\,U - 18.72391\,V + 12.66341\,U^2 - 32.47686\,V^2 - 52.70768\,U^3 - 13.86527\,UV^2 - 16.82734\,V^3 - 59.54646\,U^3V + 120.64887\,U^5 + 7.23362\,U^2V^3 + 95.89131\,U^5V - 2.89651\,UV^5 - 1.23778\,V^6 + 70.19213\,U^8 + 0.84596\,U^2V^6 + 0.14848\,V^8 - 3.83786\,U^3V^6 + 0.10405\,UV^9 + 30.09795\,U^8V^3 + 12.93585\,U^6V^6 - 0.58747\,U^3V^9 + 0.74850\,U^4V^9 + 6.32462\,U^8V^7 - 0.12736\,U^6V^9 - 0.59993\,U^9V^9$$

$$\Delta\lambda'' = -0.33643 - 3.11777\,V - 5.16881\,U^2 - 3.17318\,V^2 - 34.59331\,U^3 + 0.97215\,UV^2 - 0.58180\,V^3 + 223.78114\,U^5 + 358.07266\,U^6 + 270.68064\,U^7 - 87.99549\,U^6V - 0.09789\,UV^6 + 636.41982\,U^7V - 729.91514\,U^6V^2 - 0.60122\,U^3V^5 - 375.38863\,U^6V^3 - 6.97538\,U^4V^5 - 0.00138\,V^9 - 363.45977\,U^9V + 50.19955\,U^8V^2 - 12.01575\,U^5V^6 - 0.43140\,U^6V^9 + 0.43907\,U^9V^9$$

$$\Delta H_m = -20.013 + 12.815\,U - 8.084\,V + 74.122\,U^2V + 39.523\,U^2V^2 - 23.158\,U^4V + 194.444\,U^6 + 36.797\,U^5V + 0.181\,UV^5 - 292.155\,U^8 + 3.749\,U^5V^5 + 2.537\,U^8V^6$$

In the preceding equations:

$U = K\,(\phi - 20)$
$V = K\,(\lambda - 290)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 77, 78, and 82 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.8 m; λ: ±1.9 m; H (geodetic height): ±1.5 m

Test Case:

Input data for NAD 27 (Mexico, Central America) test point:	ϕ =	8°56'12.719"N	$\Delta\phi$ =	4.681"
	λ =	280°25'46.382"E	$\Delta\lambda$ =	0.722"
			ΔH =	-26.36 m

Table 20.35

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Old Egyptian Datum* to WGS 84 -

$$\Delta\phi'' = 0.47505 + 0.40361\,U - 0.33767\,V - 0.47316\,UV + 0.14675\,V^2 + 0.53103\,U^3 - 0.91154\,U^5 - 1.80678\,U^3V^4 - 0.93280\,U^2V^8 + 3.45171\,U^9V^6 + 2.48260\,U^7V^9$$

$$\Delta\lambda'' = 5.81106 + 0.30856\,U + 0.30619\,V - 0.09563\,UV + 0.33431\,V^2 - 0.37812\,V^3 - 0.11075\,U^2V^2 - 0.19767\,U^5 - 0.87801\,U^3V^2 - 0.40334\,V^6 + 1.50782\,U^7V^4$$

$$\Delta H_m = 6.689 + 14.900\,V + 5.562\,U^2 - 7.102\,UV - 7.972\,UV^2 + 3.923\,U^5 - 15.171\,U^8V - 12.559\,V^9 - 24.444\,U^6V^8$$

In the preceding equations:

$U = K\,(\phi - 27)$
$V = K\,(\lambda - 30)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 30, 29, and 29 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.3 m; λ: ±1.2 m; H (geodetic height): ±1.1 m

Test Case:

Input data for Old Egyptian Datum test point:	ϕ = 29°50°02.352"N	$\Delta\phi$ =	0.635"
	λ = 30°35°58.098"E	$\Delta\lambda$ =	5.972"
		ΔH =	8.93 m

* Egypt

Table 20.36

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Old Hawaiian Datum* to WGS 84 -

$$\Delta\phi'' = -11.37720 - 0.14634\,V - 0.12247\,V^2 - 0.73184\,UV^2 + 1.11437\,U^2V^2 - 1.01133\,UV^3 + 4.16524\,U^3V^5 - 3.15868\,U^5V^7 - 0.93803\,U^8V^9$$

$$\Delta\lambda'' = 9.86069 - 0.06272\,V - 0.19525\,UV + 0.68017\,V^2 + 0.00368\,U^3 - 0.26472\,U^2V - 0.90367\,V^4 + 0.43038\,V^5 - 0.05705\,U^9V^6$$

$$\Delta H_m = 19.743 - 6.792\,U + 14.315\,V - 2.336\,V^2 - 10.929\,UV^3 + 8.248\,UV^4 + 2.176\,U^9V^6$$

In the preceding equations:

$U = K\,(\phi - 21)$
$V = K\,(\lambda - 202)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 27 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.2 m; λ: ±0.8 m; H (geodetic height): ±1.4 m

Test Case:

Input data for Old Hawaiian Datum test point:	ϕ = 21°34'22.580"N	$\Delta\phi$ = -11.364"
	λ = 201°44'13.631"E	$\Delta\lambda$ = 9.883"
		ΔH = 16.51 m

* Hawaii, Kauai, Maui, and Oahu Islands

Table 20.37

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Oman Datum* to WGS 84 -

$$\Delta\phi'' = 1.40340 - 0.52482\,U - 0.39298\,V + 0.06350\,U^2 + 0.43668\,V^3 - 0.24373\,V^4 + 0.02444\,U^5 + 0.25173\,U^4V^2 + 0.02988\,U^8V - 0.12828\,U^3V^6 + 0.17909\,U^4V^7$$

$$\Delta\lambda'' = 9.99946 + 0.23141\,U + 0.27637\,V - 0.15426\,U^2 + 0.05592\,UV - 0.06719\,U^2V + 0.17487\,UV^2 - 0.10007\,V^3 + 0.03666\,U^4 - 0.10515\,U^4V^9$$

$$\Delta H_m = -29.424 + 4.112\,U + 11.687\,V - 9.535\,U^2 + 7.644\,UV^2 - 11.213\,V^3 + 2.756\,U^4 + 3.699\,V^4 - 13.803\,U^3V^2 + 37.182\,U^3V^4 - 22.258\,U^4V^7$$

In the preceding equations:

$U = K\,(\phi - 21)$
$V = K\,(\lambda - 56)$
$K = 0.31415926$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 21 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.7 m; λ: ±0.9 m; H (geodetic height): ±0.5 m

Test Case:

Input data for Oman	ϕ =	24°17'39.334"N	$\Delta\phi$ =	0.908"
Datum test point:	λ =	56°31'43.374"E	$\Delta\lambda$ =	10.164"
			ΔH =	-30.50 m

* Oman

Table 20.38

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Ordnance Survey of Great Britain 1936 Datum* to WGS 84 -

$$\Delta\phi'' = 0.86569 - 2.84325\,U + 0.42841\,V - 0.38129\,U^2 + 0.10976\,V^2 + 0.94422\,U^3 + 0.48727\,U^2V + 2.60383\,U^3V + 0.45210\,U^2V^2 - 4.67120\,U^5V + 5.92805\,U^8V - 1.57065\,U^4V^5 + 9.93871\,U^9V^2 + 4.46776\,U^7V^9$$

$$\Delta\lambda'' = -6.33331 - 1.37857\,U - 3.08334\,V - 2.36779\,UV - 0.31544\,V^2 + 0.16916\,U^2V - 3.30597\,UV^2 - 0.89564\,U^2V^2 - 2.20892\,UV^3 + 10.50912\,U^8V^2 - 14.75340\,U^9V^2$$

$$\Delta H_m = 48.125 + 6.154\,U - 3.952\,V - 13.733\,U^2 + 7.185\,UV + 18.661\,U^4 - 12.149\,U^5 - 25.508\,U^3V^3 - 60.708\,U^7V^6$$

In the preceding equations:

$U = K\,(\phi - 54)$
$V = K\,(\lambda - 0)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 48, 50, and 50 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±0.8 m; λ: ±1.2 m; H (geodetic height): ±0.9 m

Test Case:

Input data for Ordnance Survey of Great Britain 1936 test point:	ϕ =	52°08'34.745"N	$\Delta\phi$ =	1.525"
	λ =	358°02'00.119"E	$\Delta\lambda$ =	-5.161"
			ΔH =	47.17 m

* United Kingdom (UK)

[Revised: 30 September 1988]

Table 20.39

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Provisional South American Datum 1956* to WGS 84 -

$$\Delta\phi'' = -12.04886 + 0.53593\,U - 0.77151\,U^2 + 0.22777\,UV + 0.80832\,V^2 + 0.22515\,V^3 + 0.60656\,U^4 - 1.45756\,V^4 - 0.04241\,U^4V - 0.19135\,U^6 + 0.05461\,U^4V^2 + 0.14627\,U^3V^3 + 0.73219\,V^6 - 0.01691\,U^7 - 1.42463\,U^2V^5 + 0.02264\,U^8 + 0.00447\,U^9 + 1.84039\,U^4V^5 - 0.00913\,U^8V^2 + 0.05740\,U^8V^3 - 1.03610\,U^6V^5 - 0.10195\,U^2V^9 + 0.10483\,U^4V^9 - 0.04520\,U^7V^7 + 0.19591\,U^8V^7 + 0.01040\,U^9V^8 - 0.06467\,U^8V^9$$

$$\Delta\lambda'' = -7.21832 + 0.45226\,U + 0.86445\,V + 0.71206\,U^2 + 0.25898\,V^2 - 0.74778\,U^3 + 0.78582\,U^2V - 0.19004\,UV^2 - 0.34575\,U^4 - 0.49115\,UV^3 + 0.28299\,U^5 - 0.38667\,U^4V + 0.05364\,U^6 - 0.07100\,V^6 - 0.03680\,U^7 + 0.04457\,U^6V + 0.50006\,UV^7 + 0.02585\,U^7V^2 + 0.04348\,U^6V^3 - 0.44328\,U^2V^7 - 0.09531\,UV^8 + 0.17935\,U^4V^8 - 0.17785\,U^5V^9 + 0.08942\,U^6V^9 + 0.13445\,U^7V^9 - 0.05018\,U^8V^9 - 0.03301\,U^9V^9$$

$$\Delta H_m = 39.322 - 192.920\,U - 26.628\,V - 151.702\,UV + 245.467\,U^3 + 158.056\,UV^2 - 3.514\,U^4 + 330.660\,U^3V + 56.517\,UV^3 - 46.597\,V^4 - 149.686\,U^5 - 72.168\,U^3V^2 - 195.728\,UV^4 - 315.032\,U^5V - 122.158\,U^4V^2 + 105.550\,U^2V^4 - 31.836\,UV^5 + 29.180\,V^6 + 32.957\,U^7 - 28.622\,U^4V^3 + 73.984\,UV^6 + 0.118\,U^8 + 128.458\,U^7V + 78.361\,U^6V^2 + 45.311\,U^4V^4 + 5.057\,UV^7 - 1.737\,U^9 + 1.030\,U^8V - 19.173\,U^9V - 15.269\,U^8V^2 + 4.161\,U^7V^3 - 23.813\,U^2V^8 + 1.458\,U^9V^2 - 2.959\,U^4V^9 - 2.432\,U^8V^6 - 3.089\,U^9V^8 + 2.797\,U^9V^9$$

*Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, Venezuela

Table 20.39 (Cont'd)

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Provisional South American Datum 1956* to WGS 84 -

In the preceding equations:

$U = K(\phi + 5)$
$V = K(\lambda - 290)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 74, 78, and 78 comparison points to the following root-mean-square (RMS) differences, respectively:

ϕ: ±1.5 m; λ: ±1.8 m; H (geodetic height): ±2.9 m

Test Case:

Input data for Provisional South American Datum 1956 test point:	ϕ = -16°31'33.903"S	$\Delta\phi$ = -13.021"
	λ = 291°50'01.014"E	$\Delta\lambda$ = -6.293"
		ΔH = 99.51 m

* Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, Venezuela

Table 20.40

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Puerto Rico Datum* to WGS 84 -

$$\Delta\phi'' = -7.07242 - 0.35983\,U + 0.09560\,V + 1.16795\,U^3$$

$$\Delta\lambda'' = 1.40909 - 0.07164\,V - 0.07947\,UV - 0.10747\,V^2$$

$$\Delta H_m = -42.510 - 2.649\,V^2$$

In the preceding equations:

$U = K\,(\phi - 18)$
$V = K\,(\lambda - 295)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 19 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.0 m; λ: ±0.9 m; H (geodetic height): ±1.0 m

Test Case:

Input data for Puerto Rico Datum test point:	ϕ = 18°22'01.523"N	$\Delta\phi$ = -7.247"
	λ = 292°44'02.548"E	$\Delta\lambda$ = 1.361"
		ΔH = -46.24 m

* Puerto Rico and the Virgin Islands

Table 20.41

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Qatar National Datum* to WGS 84 -

$$\Delta\phi'' = 2.487363 + 0.08786\ U + 0.14283\ U^2 + 0.04380\ UV + 0.07142\ V^2 - 0.08879\ UV^2 - 0.11089\ U^5 - 0.06321\ U^3V^4 + 0.01669\ U^9$$

$$\Delta\lambda'' = -\ 2.80439 + 0.10489\ V + 0.02697\ V^2 - 1.10721\ U^2V^2 + 2.88786\ U^2V^3 - 0.06281\ U^5V - 2.59921\ U^3V^6$$

$$\Delta H_m = -28.376 + 2.381\ U - 1.126\ U^2 + 3.095\ V^2 - 4.112\ U^3V^3 - 13.156\ V^7 - 2.048\ U^8 + 1.618\ U^9 + 18.689\ UV^8$$

In the preceding equations:

$U = K\ (\phi - 25)$
$V = K\ (\lambda - 51)$
$K = 1.04719754$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 15 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.3 m; λ: ±0.2 m; H (geodetic height): ±0.2 m

Test Case:

Input data for Qatar National Datum test point:	ϕ =	24°34'55.061"N	$\Delta\phi$ =	2.465"
	λ =	50°59'06.940"E	$\Delta\lambda$ =	-2.806"
			ΔH =	-29.64 m

* Qatar

[Revised: 30 September 1988]

Table 20.42

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Southwest Base Datum* to WGS 84 -

$$\Delta\phi'' = -0.40996 + 0.09162\ U^3$$

$$\Delta\lambda'' = 4.06520 + 0.10550\ V + 0.99687\ UV - 44.30616\ U^4V^2 - 15.85175\ U^3V^3 + 3905.50820\ U^7V^4$$

$$\Delta H_m = 58.268 + 1.325\ V$$

In the preceding equations:

$U = K\ (\phi - 38)$
$V = K\ (\lambda - 332)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 11 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.5 m; λ: ±0.6 m; H (geodetic height): ±0.3 m

Test Case:

Input data for Southwest Base Datum test point:	ϕ =	38°46'51.568"N	$\Delta\phi$ =	-0.404"
	λ =	332°53'52.593"E	$\Delta\lambda$ =	4.285"
			ΔH =	58.89 m

* Azores (Faial, Graciosa, Pico, São Jorge, and Terceira Islands)

Table 20.43

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Timbalai Datum 1948* to WGS 84 -

$$\Delta\phi'' = -2.82946 - 0.82553\,U - 0.48000\,V + 0.85905\,UV + 0.29818\,V^3 - 0.89297\,U^2V^2 - 1.23097\,V^4 + 4.44707\,V^6 - 59.09713\,U^7V - 3.02239\,V^8 + 7.38294\,U^9 + 123.99897\,U^9V$$

$$\Delta\lambda'' = 11.11187 - 0.82451\,U - 0.67430\,V - 5.29900\,U^2V + 4.63827\,UV^2 - 2.73892\,V^3 + 7.29643\,U^4V - 2.74536\,UV^4 + 4.19205\,U^4V^4 + 1.54402\,V^9 + 1.74379\,U^2V^9 + 64.65940\,U^9V^4$$

$$\Delta H_m = 48.403 + 4.382\,U + 8.894\,V - 5.748\,UV + 1.434\,V^2 + 13.311\,U^3 + 23.561\,V^3 - 13.367\,U^2V^2 - 289.515\,U^8V - 57.320\,U^4V^5 - 14.505\,V^9$$

In the preceding equations:

$U = K\,(\phi - 4)$
$V = K\,(\lambda - 114)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 25 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±1.0 m; λ: ±1.2 m; H (geodetic height): ±0.7 m

Test Case:

Input data for Timbalai Datum 1948 test point:	ϕ =	5°00'39.333"N	$\Delta\phi$ =	-3.071"
	λ =	115°02'46.480"E	$\Delta\lambda$ =	10.758"
			ΔH =	51.43 m

* Brunei and East Malaysia (Sarawak and Sabah)

[Revised: 30 September 1988]

Table 20.44

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Wake-Eniwetok Datum 1960* to WGS 84 -

$$\Delta\phi'' = -1.71428 - 0.01849\,U - 0.32131\,U^6 + 0.30272\,U^8$$

$$\Delta\lambda'' = -2.40312 + 0.06671\,U + 0.03496\,V + 0.17594\,U^2 - 0.02463\,UV - 0.05576\,V^2 + 0.01897\,V^3 - 0.00955\,U^2V^2 - 0.10109\,U^8$$

$$\Delta H_m = 39.951 + 0.350\,U - 5.739\,U^2 - 0.100\,V^4 + 3.308\,U^6 + 0.002\,U^2V^9$$

In the preceding equations:

$U = K\,(\phi - 9)$
$V = K\,(\lambda - 167)$
$K = 2.09439507$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 14 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.5 m; λ: ±0.4 m; H (geodetic height): ±0.5 m

Test Case:

Input data for Wake-Eniwetok Datum 1960 test point:	ϕ =	8°43'12.587"N	$\Delta\phi$ =	-1.712"
	λ =	167°44'13.400"E	$\Delta\lambda$ =	-2.378"
			ΔH =	37.37 m

* Kwajalein Atoll Area Only

Table 20.45

Local Geodetic System-to-WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
- Zanderij Datum* to WGS 84 -

$$\Delta\phi'' = -11.40903 + 0.18148\,V + 0.11629\,UV + 0.06522\,V^2 + 0.00987\,U^3V^6$$

$$\Delta\lambda'' = -4.80576 - 0.24217\,U + 0.20528\,V + 0.13820\,UV + 0.24352\,U^3 + 0.09556\,U^4 - 0.00241\,V^9 - 0.00355\,UV^9$$

$$\Delta H_m = -31.821 - 5.132\,U - 2.917\,V + 9.090\,U^2 - 1.381\,V^2 - 7.953\,U^3 + 2.007\,UV^2 - 32.124\,U^8 - 19.573\,U^9$$

In the preceding equations:

$U = K\,(\phi - 5)$
$V = K\,(\lambda - 305)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°

The preceding equations reproduced Doppler-derived WGS 84 geodetic coordinates at 21 comparison points to the following root-mean-square (RMS) differences:

ϕ: ±0.9 m; λ: ±0.9 m; H (geodetic height): ±0.8 m

Test Case:

Input data for Zanderij Datum test point:	ϕ =	5°27'09.451"N	$\Delta\phi$ =	-11.431"
	λ =	304°47'47.486"E	$\Delta\lambda$ =	-4.885"
			ΔH =	-32.33 m

* Surinam

[Revised: 30 September 1988]

Table 20.46
Local Geodetic System to WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
for Remaining Local Geodetic Systems*

Local Geodetic System	Transformation Parameters			Number of Doppler Stations Used to Determine Transformation Parameters	Reference Ellipsoid
	$\Delta\phi$	$\Delta\lambda$	ΔH		
ADINDAN					
Mali	2.375"	-1.487"	33 m	1	Clarke 1880
Senegal	2.453	-1.838	33	2	Clarke 1880
AFGOOYE					
Somalia	1.644	-2.733	-36	1	Krassovsky
AIN EL ABD 1970					
Bahrain Island	1.743	-1.587	-27	1	International
ANNA 1 ASTRO 1965					
Cocos Islands	14.106	15.201	-33	1	Australian National
ASCENSION ISLAND 1958					
Ascension Island	1.482	1.693	18	1	International
ASTRO BEACON "E"					
Iwo Jima Island	-9.383	-5.309	61	1	International
ASTRO B4 SOROL ATOLL					
Tern Island	-10.981	4.930	25	1	International
ASTRO DOS 71/4					
St. Helena Island	-17.216	17.325	20	1	International

* Supplements the Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations in Tables 20.1 through 20.45.

Table 20.46 (Cont'd)
Local Geodetic System to WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
for Remaining Local Geodetic Systems*

Local Geodetic System	Transformation Parameters			Number of Doppler Stations Used to Determine Transformation Parameters	Reference Ellipsoid
	$\Delta\phi$	$\Delta\lambda$	ΔH		
ASTRONOMIC STATION 1952					
Marcus Island	-0.105"	5.540"	31 m	1	International
DOS 1968					
Gizo Island (New Georgia Islands)	-24.742	3.002	68	1	International
EASTER ISLAND 1967					
Easter Island	2.517	5.448	-5	1	International
EUROPEAN DATUM 1950					
Sardinia	-3.630	-3.580	52	2	International
Sicily	-4.046	-2.433	42	3	International
GANDAJIKA BASE					
Republic of Maldives	1.547	1.109	-95	1	International
GUX 1 ASTRO					
Guadalcanal Island	-24.812	3.626	67	1	International
HONG KONG 1963					
Hong Kong	-5.496	8.858	-4	2	International
INDIAN					
Bangladesh, India, and Nepal	**	**	**	**	Everest

* Supplements the Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations in Tables 20.1 through 20.45.

** Contact DMA (see PREFACE) if data in this form is needed for this datum or area.

Table 20.46 (Cont'd)
Local Geodetic System to WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
for Remaining Local Geodetic Systems*

Local Geodetic System	Transformation Parameters			Number of Doppler Stations Used to Determine Transformation Parameters	Reference Ellipsoid
	$\Delta\phi$	$\Delta\lambda$	ΔH		
ISTS 073 ASTRO 1969 Diego Garcia	-8.121"	-10.732"	-71 m	2	International
JOHNSTON ISLAND 1961 Johnston Island	-6.369	3.746	18	1	International
KERGUELEN ISLAND Kerguelen Island	1.974	-9.875	38	1	International
L.C.5 ASTRO Cayman Brac Island	0.848	2.159	-16	1	Clarke 1866
LUZON Mindanao Island	-3.998	5.014	71	1	Clarke 1866
MAHE 1971 Mahe Island	-2.942	-5.146	-37	1	Clarke 1880
MARCO ASTRO Salvage Islands	3.099	-7.425	47	1	International
MASSAWA Eritrea (Ethiopia)	-3.469	-2.878	6	1	Bessel 1841

* Supplements the Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations in Tables 20.1 through 20.45.

Table 20.46 (Cont'd)
Local Geodetic System to WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
for Remaining Local Geodetic Systems*

Local Geodetic System	Transformation Parameters			Number of Doppler Stations Used to Determine Transformation Parameters	Reference Ellipsoid
	$\Delta\phi$	$\Delta\lambda$	ΔH		
MIDWAY ASTRO 1961 Midway Island	46.597"	3.663"	10 m	1	International
NAHRWAN Saudi Arabia	9.260	1.722	-18	1	Clarke 1880
NAPARIMA, BWI Trinidad and Tobago	6.363	5.754	-47	1	International
NAD 27 Greenland (Hayes Peninsula)	1.190	7.182	11	2	Clarke 1866
OBSERVATORIO 1966 Corvo and Flores Islands (Azores)	4.812	-15.256	57	3	International
PICO DE LAS NIEVES Canary Islands	5.317	-6.247	50	1	International
PITCAIRN ASTRO 1967 Pitcairn Island	0.131	1.250	-6	1	International
PROVISIONAL SOUTH CHILEAN 1963 South Chile (Near 53°S)	0.039	4.385	11	2	International
QORNOQ South Greenland	-5.335	16.027	14	2	International

* Supplements the Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations in Tables 20.1 through 20.45.

Table 20.46 (Cont'd)
Local Geodetic System to WGS 84
Datum Transformation Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)
for Remaining Local Geodetic Systems*

Local Geodetic System	Transformation Parameters			Number of Doppler Stations Used to Determine Transformation Parameters	Reference Ellipsoid
	$\Delta\phi$	$\Delta\lambda$	ΔH		
REUNION Mascarene Island	-44.792"	-21.237"	9 m	1	International
ROME 1940 Sardinia Island	2.222	-1.345	42	1	International
SANTO (DOS) Espirito Santo Island	2.805	-2.630	72	1	International
SÃO BRAZ São Miguel, Santa Maria Islands (Azores)	3.312	1.644	56	2	International
SAPPER HILL 1943 East Falkland Island	-0.763	-15.209	11	1	International
SCHWARZECK Namibia	-2.336	-2.953	19	3	Bessel 1841
SOUTH ASIA Singapore	-0.837	-0.153	6	1	Modified Fischer 1960
SOUTHEAST BASE Porto Santo and Madeira Islands	13.033	-14.685	52	2	International
TRISTAN ASTRO 1968 Tristan da Cunha	-26.823	11.877	17	1	International
VITI LEVU 1916 Viti Levu Island (Fiji Islands)	5.141	-13.327	59	1	Clarke 1880

* Supplements the Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations in Tables 20.1 through 20.45.

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SECTION 21

HISTOGRAMS

- WGS 84 COORDINATE DIFFERENCES* (MAJOR DATUMS) -

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* WGS 84 COORDINATES OBTAINED FROM DOPPLER-DERIVED NSWC 9Z-2 COORDINATES USING NSWC 9Z-2 TO WGS 84 TRANSFORMATION MINUS WGS 84 COORDINATES COMPUTED USING LOCAL GEODETIC SYSTEM-TO-WGS 84 DATUM TRANSFORMATION MULTIPLE REGRESSION EQUATIONS (SECTION 19); UNITS = METERS

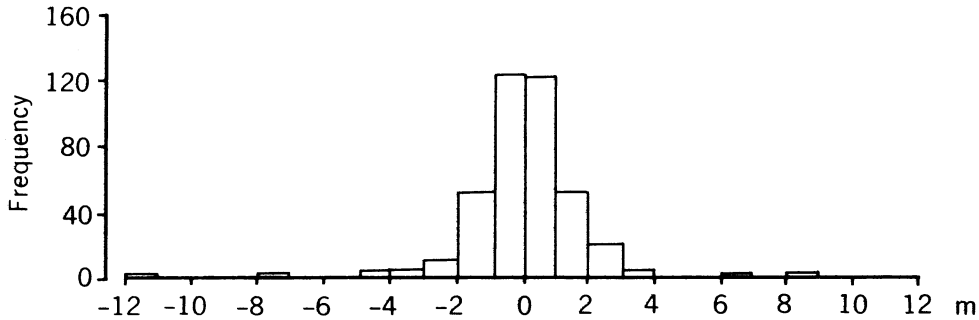

Figure 21.1a. NAD 27 (CONUS)-Geodetic Latitude Differences*

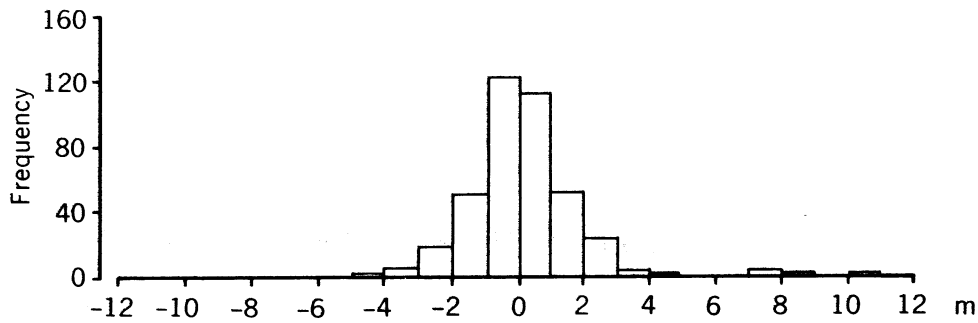

Figure 21.1b. NAD 27 (CONUS)-Geodetic Longitude Differences*

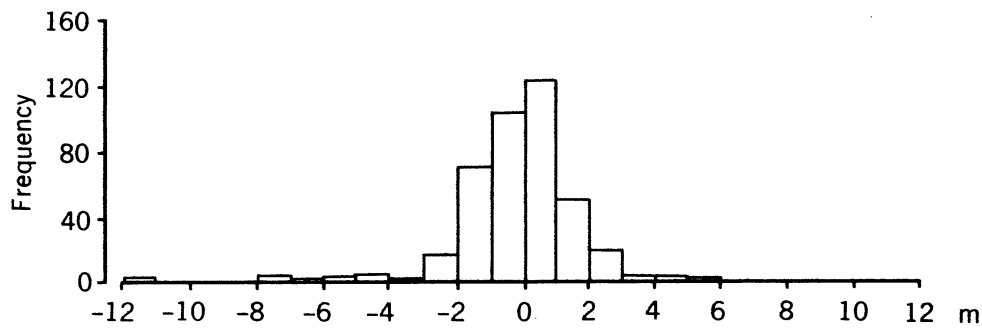

Figure 21.1c. NAD 27 (CONUS)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using NAD 27 (CONUS)-to-WGS 84 Datum Transformation Multiple Regression Equations.

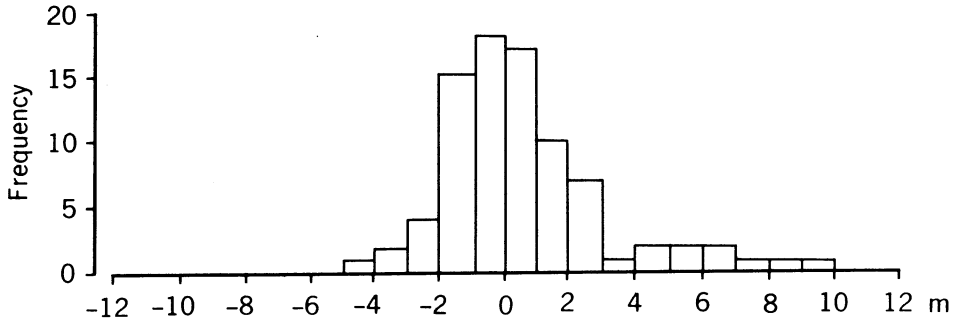

Figure 21.2a. SAD 69-Geodetic Latitude Differences*

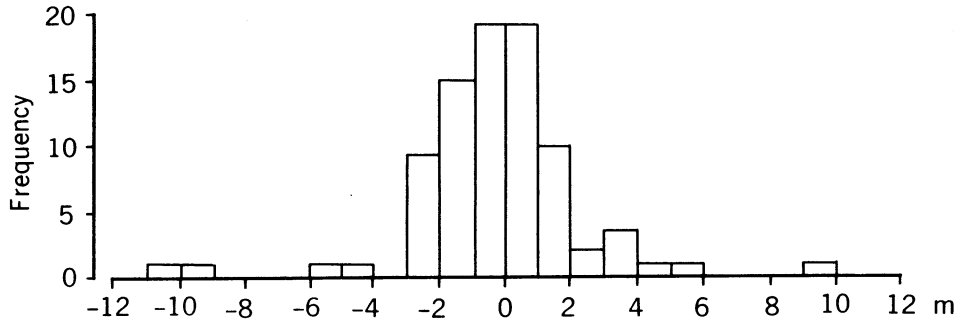

Figure 21.2b. SAD 69-Geodetic Longitude Differences*

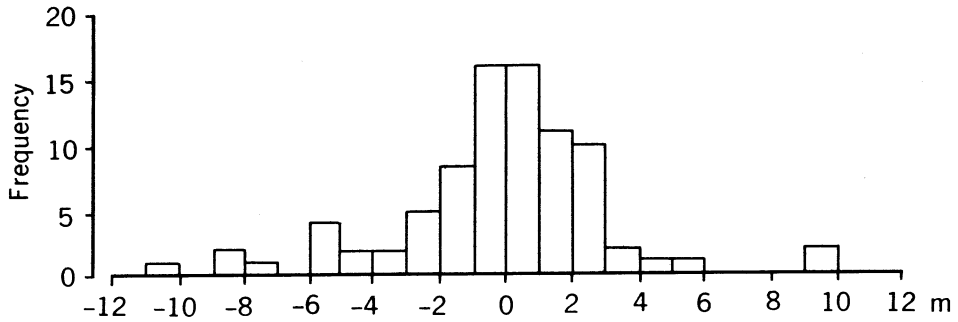

Figure 21.2c. SAD 69-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using SAD 69-to-WGS 84 Datum Transformation Multiple Regression Equations.

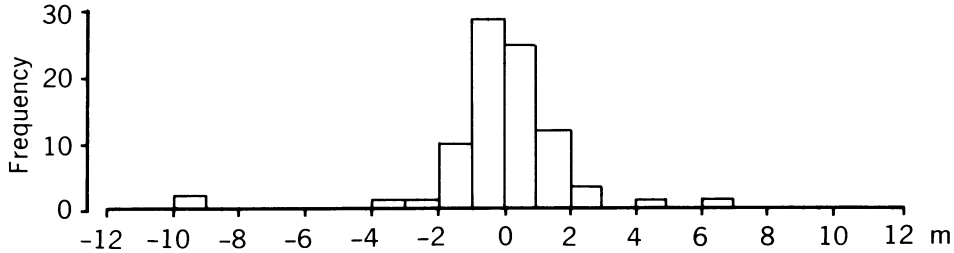

Figure 21.3a. ED 50 (Western Europe)-Geodetic Latitude Differences*

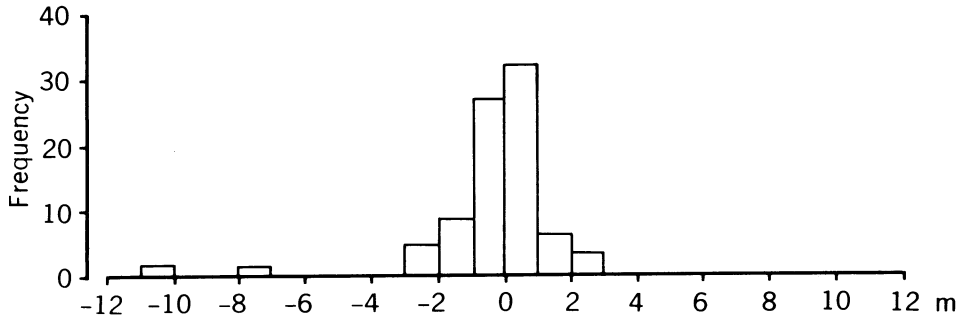

Figure 21.3b. ED 50 (Western Europe)-Geodetic Longitude Differences*

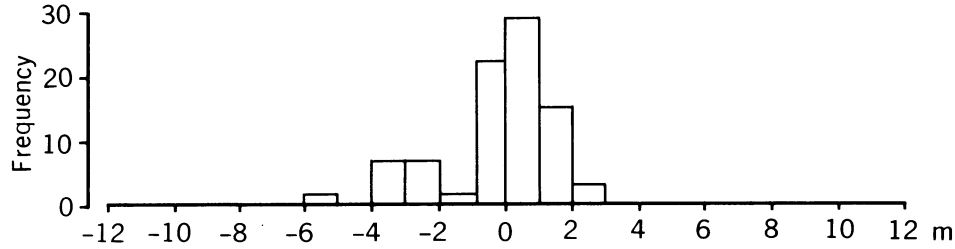

Figure 21.3c. ED 50 (Western Europe)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using ED 50 (Western Europe)-to-WGS 84 Datum Transformation Multiple Regression Equations.

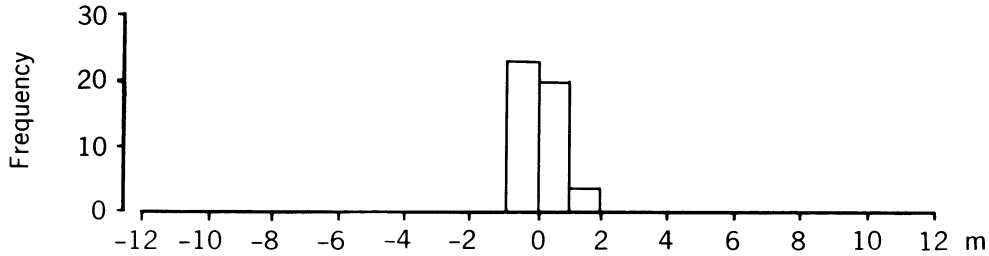

Figure 21.4a. ED 50 (UK/Ireland)-Geodetic Latitude Differences*

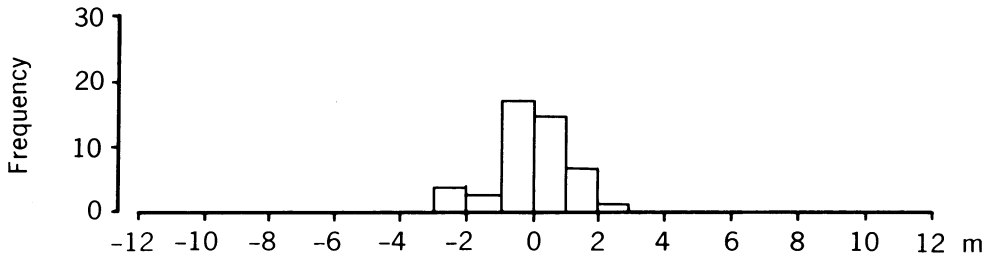

Figure 21.4b. ED 50 (UK/Ireland)-Geodetic Longitude Differences*

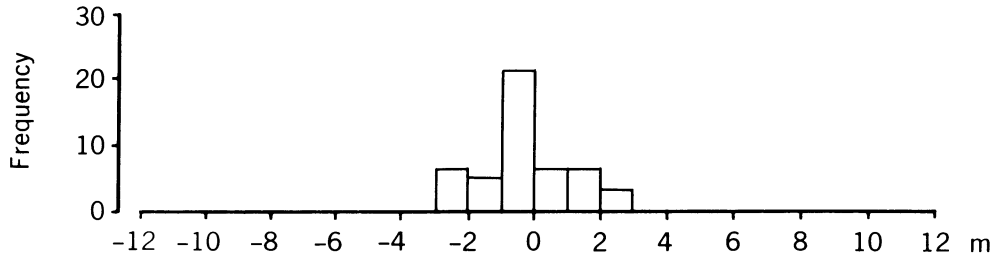

Figure 21.4c. ED 50 (UK/Ireland)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using ED 50 (UK/Ireland)-to-WGS 84 Datum Transformation Multiple Regression Equations.

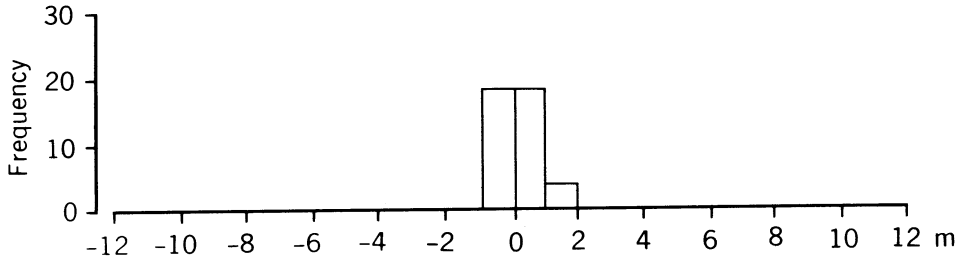

Figure 21.5a. ED 50 (UK Only)-Geodetic Latitude Differences*

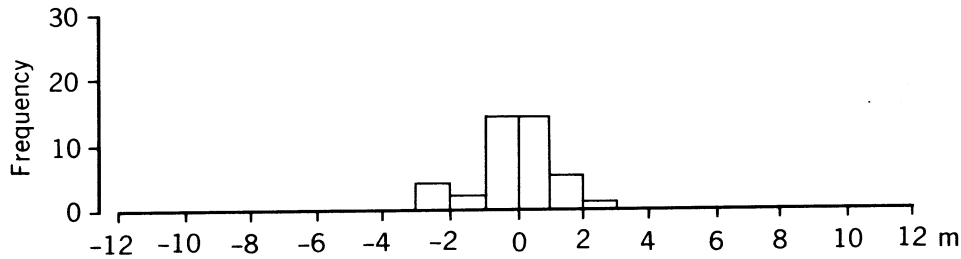

Figure 21.5b. ED 50 (UK Only)-Geodetic Longitude Differences*

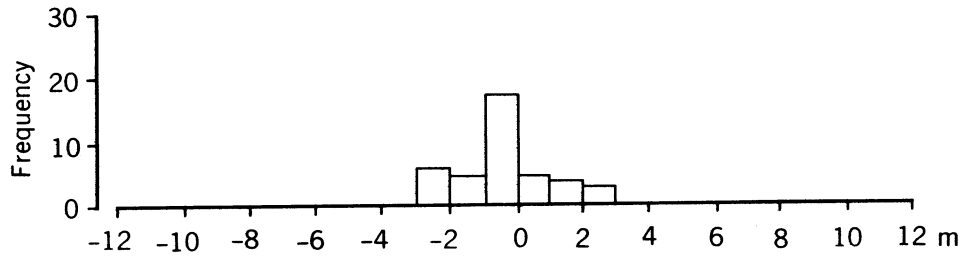

Figure 21.5c. ED 50 (UK Only)-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using ED 50 (UK Only)-to-WGS 84 Datum Transformation Multiple Regression Equations.

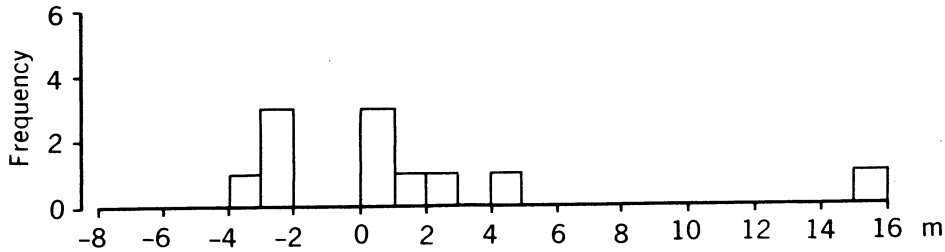

Figure 21.6a. TD-Geodetic Latitude Differences*

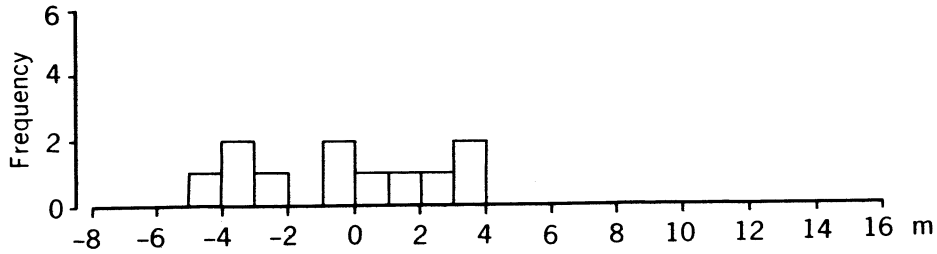

Figure 21.6b. TD-Geodetic Longitude Differences*

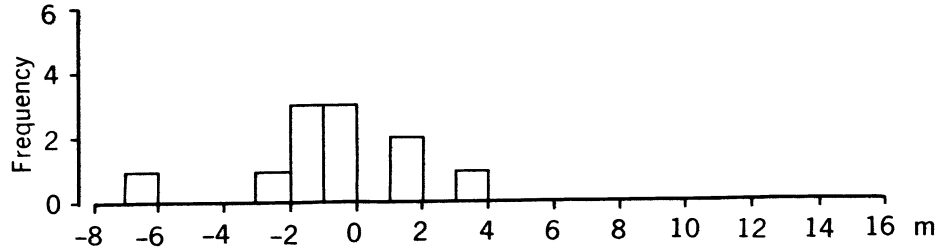

Figure 21.6c. TD-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using TD-to-WGS 84 Datum Transformation Multiple Regression Equations.

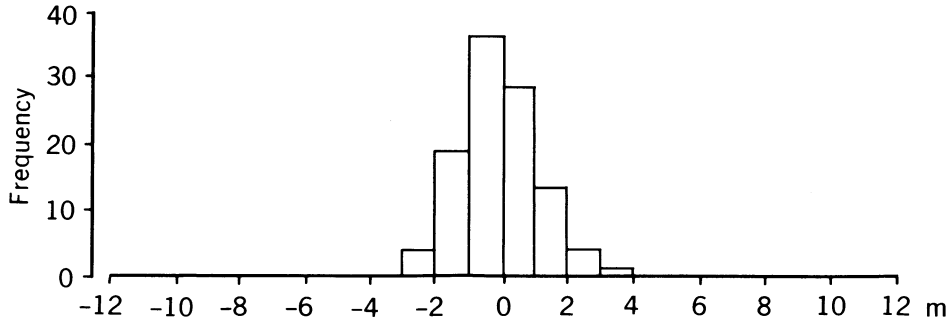

Figure 21.7a. AGD 66-Geodetic Latitude Differences*

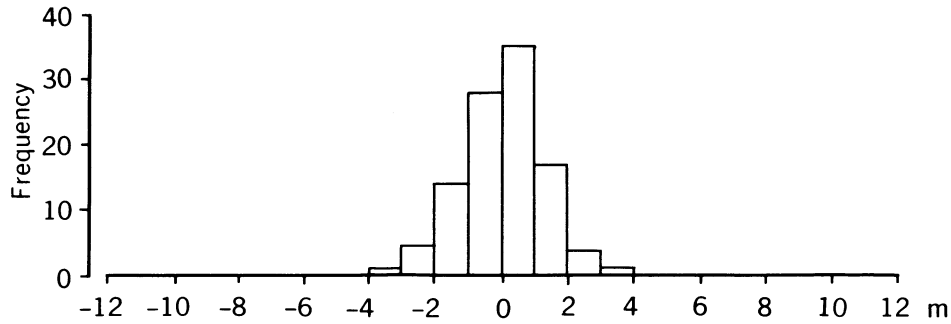

Figure 21.7b. AGD 66-Geodetic Longitude Differences*

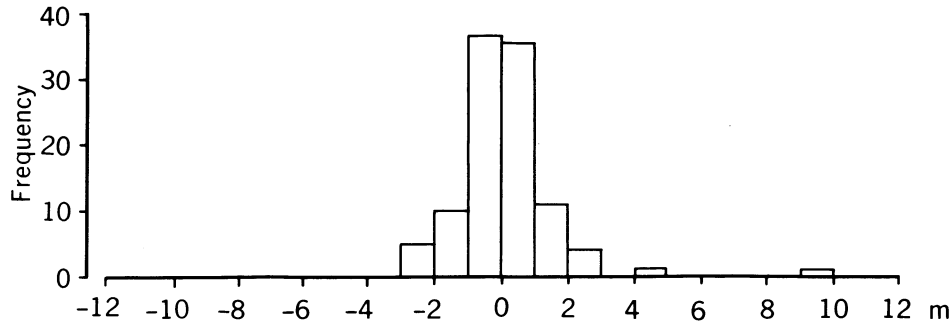

Figure 21.7c. AGD 66-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using AGD 66-to-WGS 84 Datum Transformation Multiple Regression Equations.

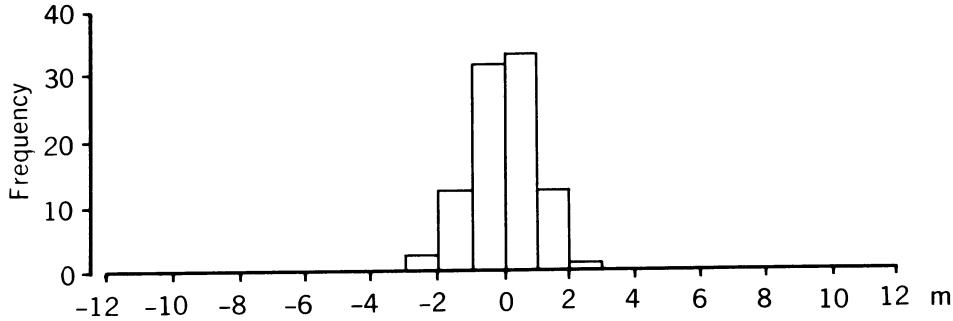

Figure 21.8a. AGD 84-Geodetic Latitude Differences*

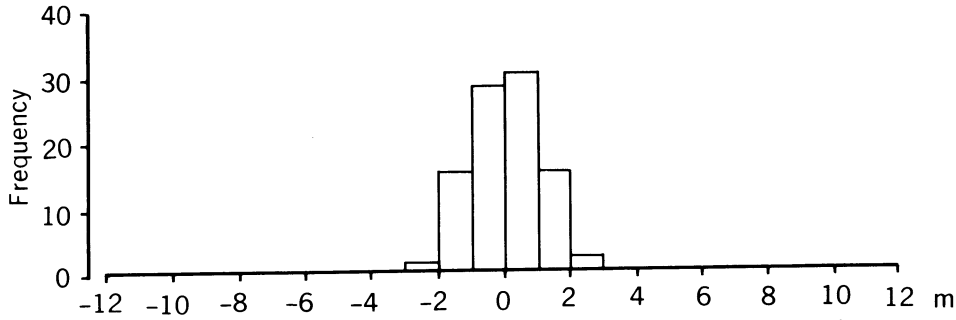

Figure 21.8b. AGD 84-Geodetic Longitude Differences*

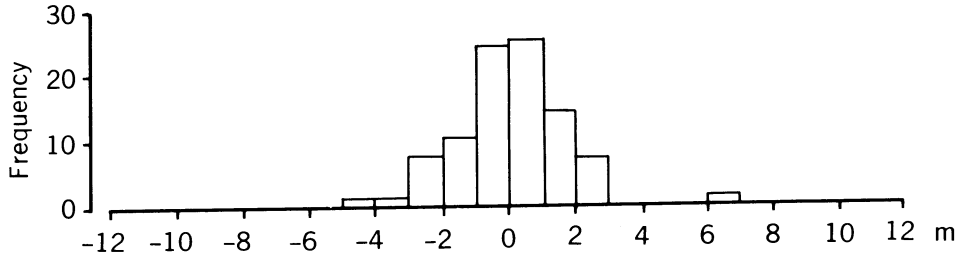

Figure 21.8c. AGD 84-Geodetic Height Differences*

*Differences = WGS 84 Coordinates Obtained From Doppler-Derived NSWC 9Z-2 Coordinates Minus WGS 84 Coordinates Computed Using AGD 84-to-WGS 84 Datum Transformation Multiple Regression Equations.

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SECTION 22

MULTIPLE REGRESSION EQUATIONS
FOR
DMA-DEVELOPED LOCAL GEODETIC SYSTEM GEOID HEIGHTS
- MAJOR DATUMS -

Table 22.1

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- North American Datum 1927 (NAD 27)* -

$$
\begin{aligned}
N_m = {} & 5.068 - 11.570\,U - 8.574\,V + 27.839\,U^2 - 51.911\,UV + 29.496\,V^2 + 28.343\,U^3 + 24.481\,UV^2 \\
& + 11.424\,V^3 + 132.550\,U^3V - 110.232\,U^2V^2 + 41.018\,UV^3 - 64.953\,V^4 - 128.293\,U^3V^2 \\
& + 51.241\,UV^4 - 4.326\,V^5 + 104.097\,U^4V^2 - 128.031\,U^3V^3 + 110.694\,U^2V^4 + 36.330\,V^6 \\
& + 243.149\,U^6V - 15.790\,U^2V^5 - 38.043\,UV^6 - 40.277\,U^2V^6 + 2.746\,UV^7 - 7.321\,V^8 - 394.404\,U^9 \\
& - 927.540\,U^8V + 63.390\,U^4V^5 + 10.626\,UV^8 - 0.520\,UV^9 - 117.207\,U^8V^4 + 16.352\,U^5V^8
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi - 37)$
$V = K\,(\lambda - 265)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.3 meters; 444 sites involved in the comparison.

Test Case:

Input data for NAD 27 test point: ϕ = 34°47'08.833"N, λ = 273°25'07.825"E

N = 8.63 m (Clarke 1866 Ellipsoid)

* Contiguous United States (CONUS); Clarke 1866 Ellipsoid

Table 22.2

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- South American Datum 1969 (SAD 69)* -

$$
\begin{aligned}
N_m = {} & 15.895 - 53.992\,V - 66.142\,U^2 - 43.870\,UV - 9.190\,V^2 + 2.500\,U^3 + 52.410\,U^2V + 47.049\,UV^2 \\
& + 102.468\,V^3 + 63.393\,U^4 + 119.668\,U^3V + 73.935\,U^2V^2 - 30.577\,UV^3 - 56.235\,V^4 - 130.660\,U^3V^2 \\
& - 126.489\,U^2V^3 + 61.258\,UV^4 - 27.268\,U^6 - 139.477\,U^5V + 34.550\,U^5V^2 + 57.270\,U^4V^3 + 4.265\,U^8 \\
& + 51.993\,U^7V - 12.634\,UV^7 - 0.422\,U^9 - 0.838\,U^8V + 1.812\,U^5V^4 - 6.048\,U^9V + 37.272\,U^3V^7 \\
& - 8.841\,U^4V^8 - 10.368\,U^6V^9
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi + 20)$
$V = K\,(\lambda - 300)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed SAD 69 geoid height (in meters) referenced to the South American 1969 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±2.0 meters; 140 sites involved in the comparison.

Test Case:

Input data for SAD 69 test point: ϕ = -31°56'33.954"S, λ = 294°53'41.342"E

N = 3.29 m (South American 1969 Ellipsoid)

* South American 1969 Ellipsoid

Table 22.3

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- European Datum 1950 (ED 50)* -

$$
\begin{aligned}
N_m = {} & 6.243 - 7.665\,U + 12.177\,V + 12.886\,U^2 - 15.822\,UV - 28.812\,V^2 + 276.220\,U^3 - 26.228\,U^2V \\
& - 29.689\,V^3 - 77.289\,U^4 - 64.583\,UV^3 + 40.908\,V^4 - 971.154\,U^5 + 136.704\,UV^4 + 169.545\,U^3V^3 \\
& + 14.103\,V^6 + 1495.212\,U^7 - 585.474\,U^3V^4 + 78.974\,U^8 - 83.519\,U^2V^6 - 805.496\,U^9 + 435.717\,U^4V^5 \\
& + 496.171\,U^7V^4 - 13.104\,U^6V^5 - 493.747\,U^6V^6 - 211.226\,U^9V^5 + 675.597\,U^7V^7 \\
& - 255.127\,U^9V^6 - 193.052\,U^9V^8
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi - 52)$
$V = K\,(\lambda - 10)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed ED 50 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 116 sites involved in the comparison.

Test Case:

Input data for ED 50 test point: ϕ = 46°41'42.893"N, λ = 13°54'54.088"E

N = 6.08 m (International Ellipsoid)

* Western Europe Only; International Ellipsoid

[Revised: 30 September 1988]

Table 22.4

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- European Datum 1950 (ED 50)* -

$$N_m = 0.695 + 13.023\ U - 7.961\ V - 12.715\ UV + 15.997\ V^2 + 42.321\ V^3 + 19.513\ V^4 - 102.636\ U^3V^2 - 75.046\ U^4V^2 - 512.671\ U^5V^3 - 0.996\ V^9$$

In the preceding equation:

$U = K\ (\ \phi - 54\ )$
$V = K\ (\ \lambda - 0\ )$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed ED 50 geoid height (in meters) referenced to International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.4 meter; 66 sites involved in the comparison.

Test Case:

Input data for ED 50 test point: ϕ = 49°42'40.562"N, λ = 357°48'11.987"E N = -4.03 m (International Ellipsoid)

* United Kingdom (UK)/Ireland; International Ellipsoid; ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates.

[Revised: 30 September 1988]

Table 22.5

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- European Datum 1950 (ED 50)* -

$$N_m = 1.115 + 12.154\ U - 8.575\ V - 3.183\ U^2 - 17.908\ UV + 41.262\ U^3V + 27.707\ V^5 + 81.058\ U^9 - 30.843\ V^9$$

In the preceding equation:

$U = K\ (\ \phi - 54\ )$
$V = K\ (\ \lambda - 0\ )$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed ED 50 geoid height (in meters) referenced to International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 55 sites involved in the comparison.

Test Case:

Input data for ED 50 test point: ϕ = 49°42'40.562"N, λ = 357°48'11.987"E

N = - 4.08 m (International Ellipsoid)

---

* United Kingdom (UK) Only; International Ellipsoid; ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates. The equations in Table 22.4 are recommended for geoid heights computations for United Kingdom (UK)/Ireland. Datum transformation equations in Table 19.4 are also recommended for compatibility.

[Revised: 30 September 1988]

Table 22.6

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Tokyo Datum (TD)* -

$$N_m = 19.004 - 37.468\,U + 31.786\,V + 3.470\,UV - 4.018\,U^3 + 1.326\,UV^2 - 8.480\,V^3 - 3.724\,U^3V + 7.243\,U^2V^2 - 4.923\,V^4 + 0.293\,U^9V^2 - 0.225\,U^5V^6 + 0.200\,U^2V^9$$

In the preceding equation:

$U = K\,(\phi - 35)$
$V = K\,(\lambda - 135)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed TD geoid height (in meters) referenced to the Bessel 1841 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.5 meters; 51 sites involved in the comparison.

Test Case:

Input data for TD test point: ϕ = 40°42'38.260"N, λ = 141°22'23.979"E

N = 8.46 m (Bessel 1841 Ellipsoid)

* Bessel 1841 Ellipsoid

Table 22.7

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Australian Geodetic Datum 1966 (AGD 66)* -

$$
\begin{aligned}
N_m = & - 4.258 + 2.740\ U + 70.479\ U^2 - 34.946\ UV + 12.676\ V^2 + 24.680\ U^2V - 348.586\ U^4 \\
& - 14.488\ U^2V^2 + 122.302\ UV^3 + 37.035\ U^5 - 17.307\ UV^4 - 6.704\ V^5 + 645.556\ U^6 \\
& - 80.304\ U^3V^3 - 108.866\ UV^5 - 19.475\ U^7 - 271.301\ U^4V^3 - 430.089\ U^8 \\
& - 5.561\ V^8 + 97.772\ U^8V^2 + 449.462\ U^6V^4 - 69.354\ U^2V^8 - 692.991\ U^7V^4 \\
& + 265.504\ U^3V^9 + 1311.842\ U^9V^5
\end{aligned}
$$

In the preceding equation:

$U = K\ (\ \phi + 27\ )$
$V = K\ (\ \lambda - 134\ )$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed AGD 66 geoid height (in meters) referenced to the Australian National Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.4 meters; 134 sites involved in the comparison.

Test Case:

Input data for AGD 66 test point: ϕ = -17°00'32.776"S, λ = 144°11'37.245"E

N = 0.58 m (Australian National Ellipsoid)

* Australian National Ellipsoid

Table 22.8

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Australian Geodetic Datum 1984 (AGD 84)* -

$$
\begin{aligned}
N_m = & - 4.155 + 3.939\,U + 14.693\,V + 65.144\,U^2 - 18.651\,UV + 10.460\,V^2 - 120.684\,V^3 - 267.125\,U^4 \\
& + 39.025\,UV^3 - 74.039\,U^4V - 26.446\,UV^4 + 301.719\,V^5 + 445.176\,U^6 - 33.732\,UV^5 + 16.358\,V^6 \\
& + 384.399\,U^4V^3 - 312.773\,V^7 - 257.076\,U^8 - 122.384\,U^5V^3 - 117.856\,U^2V^6 - 18.365\,V^8 \\
& - 502.439\,U^4V^5 + 9.820\,UV^8 + 110.502\,V^9 + 54.807\,U^9V + 915.970\,U^5V^7 - 3661.876\,U^7V^8 \\
& + 3579.951\,U^9V^9
\end{aligned}
$$

In the preceding equation:

$U = K\,(\,\phi + 27\,)$
$V = K\,(\,\lambda - 134\,)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed AGD 84 geoid height (in meters) referenced to the Australian National Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 109 sites involved in the comparison.

Test Case:

Input data for AGD 84 test point: ϕ = -20°38'00.673"S, λ = 144°24'29.288"E

N = 1.06 m (Australian National Ellipsoid)

* Australian National Ellipsoid

Table 22.9

RMS Difference With Which Geoid Height Multiple Regression Equations Reproduce DMA-Developed Local Geodetic System Geoid Heights

Local Geodetic System	- RMS Difference - Original Minus Computed (ΔN)	Number of Comparison Points
NAD 27*	± 1.3 m	444
SAD 69	2.0	140
ED 50 (Western Europe)**	1.0	116
ED 50 (UK/Ireland)***	0.4	66
ED 50 (UK Only)***	0.5	55
TD	1.5	51
AGD 66	1.4	134
AGD 84	1.2	109

* Contiguous United States (CONUS)

** Austria, Belgium, Denmark, Finland, France, FRG (Federal Republic of Germany), Gibraltar, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland

*** European Datum 1950 coordinates developed from Ordnance Survey of Great Britain (OSGB) Scientific Network 1980 (SN 80) coordinates

[Revised: 30 September 1988]

SECTION 23

MULTIPLE REGRESSION EQUATIONS

FOR DMA-DEVELOPED LOCAL GEODETIC SYSTEM GEOID HEIGHTS

- REMAINDER OF 83 LOCAL GEODETIC SYSTEMS* -

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* EQUATION NOT INCLUDED FOR EUROPEAN DATUM 1979 (SINCE IT DOES NOT REPLACE ED 50). GEOID HEIGHTS ARE APPROXIMATELY CONSTANT FOR SMALL ISLAND DATUMS AND/OR DATUMS REPRESENTING SMALL GEOGRAPHICAL AREAS. TABLE 23.43 CONTAINS GEOID HEIGHT VALUES FOR SUCH LOCAL GEODETIC SYSTEMS.

Table 23.1

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Adindan Datum* -

$$N_m = -1.412 - 2.891\,U - 13.987\,V + 8.733\,U^2 - 4.984\,V^3 - 4.455\,U^2V^2 - 6.225\,UV^3 - 1.678\,V^4$$
$$- 4.948\,U^4V + 15.649\,U^3V^3 - 2.853\,U^3V^6 - 8.902\,U^9V^3 + 0.096\,U^3V^9 + 1.257\,U^9V^5$$

In the preceding equation:

$U = K\,(\phi - 14)$
$V = K\,(\lambda - 32)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Adindan Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 50 sites involved in the comparison

Test Case:

Input data for Adindan Datum test point:	ϕ = 9°05'12.250"N λ = 36°34'48.852"E	N = -5.27 m (Clarke 1880 Ellipsoid)

* Ethiopia, Sudan; Clarke 1880 Ellipsoid

Table 23.2

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Arc Datum 1950* -

$$N_m = 0.709 - 3.012\,U - 4.491\,V + 1.982\,U^2 - 1.416\,UV - 5.672\,V^2 + 2.088\,UV^2 - 2.756\,V^3 - 4.227\,U^3V + 2.422\,U^2V^2 + 0.551\,UV^4 + 2.477\,U^5V + 0.672\,V^6 - 0.817\,U^3V^4 - 0.288\,U^7V$$

In the preceding equation:

$U = K\,(\phi + 22)$
$V = K\,(\lambda - 27)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Arc Datum 1950 geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.4 meters; 67 sites involved in the comparison.

Test Case:

Input data for Arc Datum 1950 test point:	ϕ = -21°09'03.500"S λ = 27°30'38.724"E	N = -0.07 m (Clarke 1880 Ellipsoid)

* Botswana, Lesotho, Malawi, Swaziland, Zaire, Zambia, Zimbabwe; Clarke 1880 Ellipsoid

[Revised: 30 September 1988]

Table 23.3

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Arc Datum 1960* -

$$N_m = -7.950 + 54.394\,U - 30.515\,V + 6.331\,U^2 - 42.433\,V^2 - 9.206\,U^3 - 24.156\,UV^2 + 93.603\,U^2V^2 + 75.107\,U^6 + 81.282\,V^7 - 93.656\,U^8 + 447.685\,V^8 + 58.844\,U^8V + 3078.922\,U^4V^5 - 971.193\,UV^9 - 700.255\,U^8V^3 - 8149.817\,U^4V^7 + 448.607\,U^9V^3 - 1170.336\,U^8V^4$$

In the preceding equation:

$U = K\,(\phi + 3)$
$V = K\,(\lambda - 36)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Arc Datum 1960 geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 36 sites involved in the comparison.

Test Case:

Input data for Arc Datum 1960 test point:	ϕ = -6°03'32.760"S λ = 35°55'19.249"E	N = -24.10 m (Clarke 1880 Ellipsoid)

* Kenya, Tanzania; Clarke 1880 Ellipsoid

Table 23.4

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Bogota Observatory Datum* -

$$N_m = 1.218 + 16.490\,U - 45.270\,V - 11.867\,U^2 + 4.754\,UV - 31.201\,V^2 - 38.149\,UV^2 + 73.546\,U^2V^2 + 17.376\,V^4 - 250.666\,U^2V^3 + 148.291\,UV^4 - 67.631\,U^4V^2 - 132.899\,UV^5 + 8.365\,U^6V + 136.574\,U^4V^3 + 554.970\,U^4V^5 + 677.533\,U^6V^8 + 2372.651\,U^7V^9$$

In the preceding equation:

$U = K\,(\phi - 6)$
$V = K\,(\lambda - 286)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Bogota Observatory Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 26 sites involved in the comparison.

Test Case:

Input data for Bogota Observatory Datum test point:	ϕ = 2°34'26.221"N λ = 287°21'36.733"E	N = -21.72 m (International Ellipsoid)

* Colombia; International Ellipsoid

Table 23.5

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Campo Inchauspe Datum* -

$$N_m = 0.785 + 0.892\,U - 4.421\,V + 1.539\,U^2 - 10.975\,UV + 8.042\,V^2 - 3.630\,UV^2 + 4.344\,V^3 + 9.418\,UV^3 - 6.460\,V^4 - 2.356\,U^2V^4 - 0.016\,U^8 - 0.006\,U^9 + 0.047\,U^7V^5 + 0.016\,U^8V^5$$

In the preceding equation:

$U = K\,(\phi + 35)$
$V = K\,(\lambda - 296)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Campo Inchauspe Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.6 meters; 46 sites involved in the comparison.

Test Case:

Input data for Campo Inchauspe Datum test point:	ϕ =	-29°47'45.682"S	N = -1.85 m (International Ellipsoid)
	λ =	301°52'21.803"E	

* Argentina; International Ellipsoid

Table 23.6

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Canton Astro Datum 1966* -

$$N_m = 3.255 + 3.851\ U - 4.266\ V$$

In the preceding equation:

$U = K\ (\phi + 3)$
$V = K\ (\lambda - 188)$
$K = 1.57079631$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Canton Astro Datum 1966 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.1 meter; 4 sites involved in the comparison.

Test Case:

Input data for Canton Astro Datum 1966 test point:	ϕ =	-4°29'08.524"S	N = -4.57 m (International Ellipsoid)
	λ =	187°49'32.444"E	

* Phoenix Islands; International Ellipsoid

Table 23.7

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Cape Datum* -

$$N_m = 7.444 - 3.534\ U - 22.388\ U^2 - 8.247\ V^2 - 8.640\ V^3 - 9.225\ V^6 + 58.758\ U^8$$

In the preceding equation:

$U = K\ (\phi + 28)$
$V = K\ (\lambda - 26)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Cape Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.1 meters; 32 sites involved in the comparison.

Test Case:

Input data for Cape Datum test point:	ϕ =	-22°15'13.678"S	N = -3.01 m (Clarke 1880 Ellipsoid)
	λ =	29°09'47.488"E	

* South Africa; Clarke 1880 Ellipsoid

Table 23.8

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Cape Canaveral Datum* -

$$N_m = 2.189 - 18.460\ U - 20.413\ V - 37.345\ V^2 - 458.888\ U^3V$$

In the preceding equation:

$U = K\ (\phi - 27)$
$V = K\ (\lambda - 280)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Cape Canaveral Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 26 sites involved in the comparison.

Test Case:

Input data for Cape Canaveral Datum test point:	ϕ =	26°03'36.424"N	N = 4.28 m (Clarke 1866 Ellipsoid)
	λ =	279°51'51.267"E	

* Florida and the Bahama Islands; Clarke 1866 Ellipsoid

Table 23.9

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Carthage Datum* -

$$N_m = 3.276 + 2.125\ U - 3.665\ V - 9.202\ UV - 7.095\ U^3$$

In the preceding equation:

$U = K\ (\phi - 35)$
$V = K\ (\lambda - 9)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Carthage Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 21 sites involved in the comparison.

Test Case:

Input data for Carthage Datum test point:	ϕ =	36°49'21.208"N	N = 1.03 m (Clarke 1880 Ellipsoid)
	λ =	10°46'08.814"E	

* Tunisia; Clarke 1880 Ellipsoid

Table 23.10

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Chua Astro Datum* -

$$N_m = 5.854 + 7.619\ U - 14.749\ V - 5.111\ V^2 - 1.730\ U^9$$

In the preceding equation:

$U = K\ (\phi + 25)$
$V = K\ (\lambda - 302)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Chua Astro Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 19 sites involved in the comparison.

Test Case:

Input data for Chua Astro Datum test point:	ϕ = -25°19'23.270"S λ = 305°24'47.315"E	N = -3.91 m (International Ellipsoid)

* Paraguay; International Ellipsoid

Table 23.11

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Corrego Alegre Datum* -

$$N_m = -3.024 - 22.248\,U - 5.045\,U^2 + 18.091\,UV + 55.880\,V^2 + 22.239\,U^3 + 19.927\,UV^2 - 64.427\,V^3$$
$$- 377.616\,U^4V^2 + 180.395\,U^3V^3 + 242.541\,U^2V^5 - 8.698\,U^9 + 8122.948\,U^8V^4 - 141269.020\,U^9V^9$$

In the preceding equation:

$U = K\,(\phi + 15)$
$V = K\,(\lambda - 310)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Corrego Alegre Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.1 meters; 47 sites involved in the comparison.

Test Case:

Input data for Corrego Alegre Datum test point:	ϕ =	-20°29'01.019"S	N = 7.78 m (International Ellipsoid)
	λ =	305°12'46.829"E	

* Brazil; International Ellipsoid

Table 23.12

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Djakarta Datum* -

$$N_m = -4.076 + 6.557\,U - 6.697\,U^2 + 7.434\,U^3 + 25.293\,V^3 - 16.419\,U^3V - 16.539\,V^5 - 7.800\,U^6$$

In the preceding equation:

$U = K\,(\phi - 0)$
$V = K\,(\lambda - 100)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Djakarta Datum geoid height (in meters) referenced to the Bessel 1841 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.8 meter; 17 sites involved in the comparison.

Test Case:

Input data for Djakarta Datum test point:	ϕ =	5°25'51.475"N	N = -0.51 m (Bessel 1841 Ellipsoid)
	λ =	95°32'32.178"E	

* Sumatra; Bessel 1841 Ellipsoid

Table 23.13

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- ED 50 (Cyprus)* -

$$N_m = -0.603 + 12.824\,U + 4.129\,V + 2.610\,UV - 7.982\,V^2 - 7.782\,UV^2 + 5.369\,V^3 + 3.152\,UV^4 - 2.620\,V^7 - 0.525\,UV^7 + 1.311\,V^8$$

In the preceding equation:

$U = K\,(\phi - 35)$
$V = K\,(\lambda - 33)$
$K = 0.78539816$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed ED 50 (Cyprus) geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.1 meter; 10 sites involved in the comparison.

Test Case:

Input data for ED 50 (Cyprus) test point:	ϕ =	34°43'23.316"N	N = -6.38 m (International Ellipsoid)
	λ =	32°28'06.026"E	

* International Ellipsoid

Table 23.14

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- ED 50 (Egypt)* -

$$N_m = 3.430 + 25.637\,U - 28.124\,U^2 + 26.119\,UV^2 - 8.527\,V^3 + 62.197\,U^3V + 58.308\,U^2V^3 + 158.076\,U^4V^2 + 311.812\,U^6V - 190.887\,U^9$$

In the preceding equation:

$U = K\,(\phi - 27)$
$V = K\,(\lambda - 30)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed ED 50 (Egypt) geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.8 meter; 30 sites involved in the comparison.

Test Case:

Input data for ED 50 (Egypt) test point:	ϕ =	29°50'07.103"N	N = 8.71 m (International Ellipsoid)
	λ =	30°36'05.306"E	

* International Ellipsoid

Table 23.15

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- ED 50 (Iran)* -

$$
\begin{aligned}
N_m = \; & 2.542 + 27.445\,U - 4.130\,V - 44.806\,U^2 - 37.257\,UV - 4.420\,U^3 + 7.351\,U^2V + 12.279\,UV^2 \\
& + 25.763\,U^4 + 33.240\,U^3V + 42.862\,U^2V^2 + 12.777\,UV^3 - 12.630\,V^4 - 31.975\,U^3V^2 \\
& - 28.888\,U^2V^3 - 2.519\,V^5 - 9.664\,U^4V^2 - 3.528\,U^7 - 13.384\,U^6V - 5.561\,UV^6 - 2.412\,U^8 \\
& + 2.833\,V^8 + 1.026\,V^9 - 0.241\,U^2V^9
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi - 32)$
$V = K\,(\lambda - 55)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed ED 50 (Iran) geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 47 sites involved in the comparison.

Test Case:

Input data for ED 50 (Iran) test point:	ϕ =	29°28'59.127"N	N = -17.49 m (International Ellipsoid)
	λ =	60°52'31.547"E	

* International Ellipsoid

Table 23.16

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Geodetic Datum 1949* -

$$N_m = 3.741 - 2.600\,U + 18.891\,UV - 16.708\,V^2 - 12.433\,UV^3 + 1.752\,U^7 - 117.099\,UV^6 + 62.388\,V^7 + 50.312\,U^4V^5$$

In the preceding equation:

$U = K\,(\phi + 41)$
$V = K\,(\lambda - 173)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Geodetic Datum 1949 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.3 meters; 30 sites involved in the comparison.

Test Case:

Input data for Geodetic Datum 1949 test point:	ϕ =	-41°17'32.050"S	N = 3.80 m (International Ellipsoid)
	λ =	173°15'15.405"E	

* New Zealand; International Ellipsoid

Table 23.17

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Guam Datum 1963* -

$$N_m = -7.142 + 8.306\,U - 0.567\,V + 7.076\,U^2 - 7.234\,U^3V - 0.141\,V^5 + 0.014\,U^9V + 0.003\,U^3V^9$$

In the preceding equation:

$U = K\,(\phi - 13)$
$V = K\,(\lambda - 144)$
$K = 1.57079631$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Guam Datum 1963 geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.1 meter; 6 sites involved in the comparison.

Test Case:

Input data for Guam Datum 1963 test point:	ϕ =	13°36'56.376"N	N = -2.63 m (Clarke 1866 Ellipsoid)
	λ =	144°51'25.420"E	

*Clarke 1866 Ellipsoid

Table 23.18

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Hjorsey Datum 1955* -

$$N_m = 2.466 + 11.998\ U - 2.023\ V - 24.189\ U^2 + 2.547\ UV - 2.637\ V^2$$

In the preceding equation:

$U = K\ (\phi - 64)$
$V = K\ (\lambda - 341)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Hjorsey Datum 1955 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.7 meter; 19 sites involved in the comparison.

Test Case:

Input data for Hjorsey Datum 1955 test point	ϕ = 64°31'29.258"N λ = 337°37'54.160"E	N = 3.41 m (International Ellipsoid)

* Iceland; International Ellipsoid

Table 23.19

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Indian Datum* -

$$N_m = 15.683 - 25.498\,U + 46.169\,V + 2.542\,U^2 - 2.917\,UV + 4.895\,V^2 + 1.102\,V^3 + 0.543\,U^4 + 0.376\,U^2V^2 - 0.641\,V^4 - 0.040\,V^9$$

In the preceding equation:

$U = K\,(\phi - 13)$
$V = K\,(\lambda - 103)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Indian Datum geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 40 sites involved in the comparison.

Test Case:

Input data for Indian Datum test point:	ϕ = 16°32'45.140"N λ = 107°38'49.803"E	N = 46.39 m (Everest Ellipsoid)

* Thailand and Vietnam only (Everest Ellipsoid). Contact DMA (see PREFACE) if data in this form is needed for Bangladesh, India, and Nepal.

Table 23.20

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Ireland Datum 1965* -

$$N_m = 2.181 - 1.308\ V^3 + 37.000\ U^3V^3$$

In the preceding equation:

$U = K\ (\phi - 53)$
$V = K\ (\lambda - 354)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Ireland Datum 1965 geoid height (in meters) referenced to the Modified Airy Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 22 sites involved in the comparison.

Test Case:

Input data for Ireland Datum 1965 test point:	ϕ = 54°22'26.715"N λ = 351°37'44.633"E	N = 2.23 m (Modified Airy Ellipsoid)

* Ireland; Modified Airy Ellipsoid

Table 23.21

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Kandawala Datum* -

$$N_m = -0.979 + 1.853\,U - 3.443\,U^2 + 2.523\,U^3 - 5.423\,U^2V - 5.278\,V^3 + 3.965\,U^4V^3 - 0.899\,U^7V^2 + 5.225\,U^2V^9 - 0.58513\,U^7$$

In the preceding equation:

$U = K\,(\phi - 7)$
$V = K\,(\lambda - 80)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Kandawala Datum geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.4 meter; 17 sites involved in the comparison.

Test Case:

Input data for Kandawala Datum test point:	ϕ = 7°37'02.730"N λ = 81°40'49.750"E	N = -4.55 m (Everest Ellipsoid)

* Sri Lanka; Everest Ellipsoid

Table 23.22

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Kertau Datum 1948* -

$$N_m = -3.833 - 2.701\,U + 17.861\,V + 0.386\,U^2 + 0.980\,V^2 - 0.793\,V^3 - 2.390\,UV^3 - 1.455\,U^2V^4$$

In the preceding equation:

$U = K\,(\phi - 3)$
$V = K\,(\lambda - 102)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Kertau Datum 1948 geoid height (in meters) referenced to the Modified Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.2 meter; 18 sites involved in the comparison.

Test Case:

Input data for Kertau Datum 1948 test point: ϕ = 3°27'50.710"N, λ = 102°37'24.550"E N = 0.36 m (Modified Everest Ellipsoid)

* West Malaysia and Singapore; Modified Everest Ellipsoid

Table 23.23

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Liberia Datum 1964* -

$$N_m = 5.209 + 3.083\,U + 1.475\,V - 1.843\,UV + 3.082\,U^2V + 2.535\,UV^2 - 0.808\,U^4 - 6.030\,V^4 + 5.962\,V^6 - 2.337\,V^7 + 0.147\,U^9V$$

In the preceding equation:

$U = K\,(\phi - 7)$
$V = K\,(\lambda - 350)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Liberia Datum 1964 geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.2 meter; 19 sites involved in the comparison.

Test Case:

Input data for Liberia Datum 1964 test point:	ϕ =	7°31'11.956"N	N = 6.11 m (Clarke 1880 Ellipsoid)
	λ =	351°28'54.245"E	

* Liberia; Clarke 1880 Ellipsoid

Table 23.24

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Luzon Datum* -

$$N_m = -0.695 + 3.074\,V - 10.266\,UV - 14.213\,U^2V - 26.432\,UV^2 - 14.482\,V^3 + 0.637\,U^4 + 25.562\,U^2V^3 + 0.931\,U^4V^2 + 67.489\,U^3V^3 - 55.578\,V^7 + 57.233\,U^4V^4 - 26.880\,U^4V^5 + 37.093\,V^9 + 0.399\,U^9V$$

In the preceding equation:

$U = K\,(\phi - 12)$
$V = K\,(\lambda - 122)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Luzon Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.0 meter; 34 sites involved in the comparison.

Test Case:

Input data for Luzon Datum test point:	ϕ =	6°06'29.040"N	N = -4.05 m (Clarke 1866 Ellipsoid)
	λ =	125°10'44.230"E	

* The Philippines (Except Mindanao Island); Clarke 1866 Ellipsoid

Table 23.25

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Merchich Datum* -

$$N_m = 2.782 + 18.296\,U - 3.669\,V - 36.995\,U^2 + 16.412\,UV - 8.586\,V^2 + 27.435\,U^4 + 7.039\,UV^3 + 39.471\,U^7 - 34.612\,U^9 - 0.388\,V^9 - 4.892\,U^2V^8 + 1.962\,UV^9$$

In the preceding equation:

$U = K\,(\phi - 32)$
$V = K\,(\lambda - 353)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Merchich Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.9 meter; 28 sites involved in the comparison.

Test Case:

Input data for Merchich Datum test point:	ϕ =	35°08'39.942"N	N = 7.41 m (Clarke 1880 Ellipsoid)
	λ =	357°34'13.307"E	

* Morocco; Clarke 1880 Ellipsoid

Table 23.26

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Minna Datum* -

$$N_m = 2.267 - 5.296\ U + 5.310\ V - 4.288\ V^2 + 12.235\ U^2V^2 - 16.204\ U^2V^8 - 97.314\ U^4V^8$$

In the preceding equation:

$U = K\ (\phi - 10)$
$V = K\ (\lambda - 8)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Minna Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.7 meter; 23 sites involved in the comparison.

Test Case:

Input data for Minna Datum test point:	ϕ =	9°19'09.051"N	N = 4.52 m (Clarke 1880 Ellipsoid)
	λ =	12°13'50.125"E	

* Nigeria; Clarke 1880 Ellipsoid

Table 23.27

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Nahrwan Datum* -

$$N_m = 7.464 - 3.286\ U - 3.024\ V - 3.994\ U^2 - 4.720\ V^2 - 2.019\ U^3 - 1.613\ V^3$$

In the preceding equation:

$U = K\ (\phi - 23)$
$V = K\ (\lambda - 57)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Nahrwan Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 19 sites involved in the comparison.

Test Case:

Input data for Nahrwan Datum test point:	ϕ =	24°58'07.671"N	N = 1.11 m (Clarke 1880 Ellipsoid)
	λ =	55°00'07.720"E	

* Masirah Island (Oman) and United Arab Emirates only (Clarke 1880 Ellipsoid). Contact DMA (see PREFACE) if data in this form is needed for Saudi Arabia.

Table 23.28

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Alaska*) -

$$
\begin{aligned}
N_m = \; & 1.341 + 12.556\,U + 8.458\,V + 3.742\,U^2 + 19.896\,UV + 4.249\,V^2 - 12.714\,U^3 - 4.746\,U^2V \\
& - 4.964\,UV^2 + 0.222\,V^3 - 45.166\,U^3V - 13.051\,U^2V^2 - 6.197\,UV^3 - 4.378\,V^4 + 1.472\,UV^4 \\
& - 45.658\,U^6 + 25.253\,U^5V + 23.419\,U^4V^2 + 9.917\,U^3V^3 + 1.050\,V^6 + 10.540\,U^5V^2 - 0.072\,V^8 \\
& + 37.757\,U^9 - 10.093\,U^9V^2 - 5.382\,U^7V^4 - 1.081\,U^7V^5 - 1.072\,U^8V^6
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi - 62)$
$V = K\,(\lambda - 208)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Alaska) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 92 sites involved in the comparison.

Test Case:

Input data for NAD 27 (Alaska) test point:	ϕ = 64°31'09.064"N λ = 194°37'28.092"E	N = -13.84 m (Clarke 1866 Ellipsoid)

* Clarke 1866 Ellipsoid

Table 23.29

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Canada*) -

$$
\begin{aligned}
N_m = \; & -15.483 - 12.184\,U - 12.497\,V + 50.396\,U^2 + 19.823\,UV + 2.083\,V^2 + 32.462\,U^2V + 14.999\,UV^2 \\
& + 4.955\,V^3 - 48.440\,U^2V^2 - 18.312\,UV^3 + 5.671\,V^4 - 98.935\,U^6 + 138.270\,U^4V^2 + 48.225\,U^3V^3 \\
& + 7.353\,U^2V^4 + 3.978\,UV^5 - 1.770\,V^6 + 189.722\,U^5V^2 + 71.967\,U^4V^3 - 0.050\,V^7 + 13.539\,U^3V^5 \\
& - 0.230\,UV^7 + 0.165\,V^8 - 90.371\,U^9 - 4.118\,U^4V^5 + 56.145\,U^6V^4 - 6.084\,U^3V^7 + 0.023\,UV^9 \\
& - 2.707\,U^4V^8 - 25.209\,U^8V^6 + 4.363\,U^8V^8 - 0.059\,U^9V^9
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi - 60)$
$V = K\,(\lambda - 260)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Canada) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.1 meters; 150 sites involved in the comparison.

Test Case:

Input data for NAD 27 (Canada) test point: ϕ = 54°26'08.667"N, λ = 249°42'57.590"E N = -1.99 m (Clarke 1866 Ellipsoid)

* Clarke 1866 Ellipsoid

Table 23.30

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Caribbean*) -

$$N_m = 15.540 - 33.562\,U - 29.561\,V + 10.844\,U^2 - 29.206\,V^2 - 12.738\,U^2V + 12.876\,UV^2 + 22.374\,V^3 + 11.968\,UV^3 + 29.126\,V^4 - 20.412\,UV^4 - 23.363\,V^5 + 0.596\,V^9 + 1.696\,UV^9 + 4.409\,U^2V^9 + 4.156\,U^3V^9 - 1.268\,U^9V^9$$

In the preceding equation:

$U = K\,(\phi - 20)$
$V = K\,(\lambda - 283)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Caribbean) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.3 meters; 31 sites involved in the comparison.

Test Case:

Input data for NAD 27 (Caribbean) test point: ϕ = 18°13'02.433"N, λ = 296°56'03.599"E N = -10.56 m (Clarke 1866 Ellipsoid)

* Bahama Islands (includes San Salvador Island), Barbados Island, Cuba, Dominican Republic, Grand Cayman Island, Jamaica, Leeward Islands, and Turks and Caicos Islands; Clarke 1866 Ellipsoid

[Revised: 30 September 1988]

Table 23.31

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- NAD 27 (Mexico, Central America)* -

$$
\begin{aligned}
N_m = \; & 103.590 + 447.056\,U + 219.294\,V + 144.208\,U^2 + 1094.743\,UV + 115.742\,V^2 + 643.644\,UV^2 \\
& - 68.937\,UV^4 + 5.048\,V^5 + 1942.556\,U^6 - 1357.412\,U^5V - 1064.155\,U^4V^2 - 618.937\,U^5V^2 \\
& - 851.672\,U^8 + 2044.548\,U^6V^2 - 57.758\,U^3V^5 + 3132.887\,U^8V - 1147.053\,U^7V^2 + 1.466\,UV^8 \\
& - 1303.291\,U^9V - 2.443\,U^2V^8
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi - 20)$
$V = K\,(\lambda - 290)$
$K = 0.05235988$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed NAD 27 (Mexico, Central America) geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.8 meters; 80 sites involved in the comparison.

Test Case:

Input data for NAD 27 (Mexico, Central America) test point:	ϕ =	8°56'12.719"N	N = 37.62 m (Clarke 1866 Ellipsoid)
	λ =	280°25'46.382"E	

* Clarke 1866 Ellipsoid

Table 23.32

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Old Egyptian Datum* -

$$N_m = 8.147 - 21.055\ V - 12.690\ U^2 + 6.005\ UV + 11.487\ U^3 + 9.724\ U^2V + 10.950\ UV^2 - 11.207\ U^3V^2 + 64.862\ U^4V^2 - 102.153\ U^7 - 78.986\ U^6V^2 + 105.675\ U^9$$

In the preceding equation:

$U = K\ (\phi - 27)$
$V = K\ (\lambda - 30)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Old Egyptian Datum geoid height (in meters) referenced to the Helmert 1906 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.6 meter; 30 sites involved in the comparison.

Test Case:

Input data for Old Egyptian Datum test point:	ϕ = 29°50°02.352"N λ = 30°35°58.098"E	N = 4.87 m (Helmert 1906 Ellipsoid)

* Egypt; Helmert 1906 Ellipsoid

Table 23.33

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Old Hawaiian Datum* -

$$N_m = -5.840 + 20.184\,U - 8.681\,V - 22.513\,U^2 - 17.363\,UV - 16.119\,UV^2 - 3.872\,V^3 - 14.717\,UV^3 - 4.638\,V^6 + 62.078\,U^5V^7 + 44.025\,U^6V^9$$

In the preceding equation:

$U = K\,(\phi - 21)$
$V = K\,(\lambda - 202)$
$K = 0.41887902$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Old Hawaiian Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.4 meter; 25 sites involved in the comparison.

Test Case:

Input data for Old Hawaiian Datum test point:	ϕ = 21°34'22.580"N λ = 201°44'13.631"E	N = -0.91 m (Clarke 1866 Ellipsoid)

* Hawaii, Kauai, Maui, and Oahu Islands; Clarke 1866 Ellipsoid

Table 23.34

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Oman Datum* -

$$N_m = -1.620 + 0.915\,U - 15.730\,V + 3.532\,U^2 + 5.837\,UV - 2.690\,V^6 - 6.381\,U^4V^3 - 0.511\,U^8V - 2.035\,U^8V^2$$

In the preceding equation:

$U = K\,(\phi - 21)$
$V = K\,(\lambda - 56)$
$K = 0.31415926$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Oman Datum geoid height (in meters) referenced to the Clarke 1880 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 22 sites involved in the comparison.

Test Case:

Input data for Oman Datum test point:	ϕ =	24°17'39.334"N	N = 1.28 m (Clarke 1880 Ellipsoid)
	λ =	56°31'43.374"E	

* Oman; Clarke 1880 Ellipsoid

Table 23.35

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Ordnance Survey of Great Britain 1936 Datum* -

$$N_m = -1.313 - 4.647\,U - 4.879\,V - 6.705\,UV + 2.492\,V^2 + 5.422\,U^4 - 2.836\,V^4 - 5.209\,U^3V^2$$

In the preceding equation:

$U = K\,(\phi - 54)$
$V = K\,(\lambda - 0)$
$K = 0.15707963$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 180° and negative west from 0° to -180°
N = DMA-developed Ordnance Survey of Great Britain 1936 geoid height (in meters) referenced to the Airy Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.5 meter; 52 sites involved in the comparison.

Test Case:

Input data for Ordnance Survey of Great Britain 1936 test point:	ϕ =	52°08'34.745"N	N = 1.21 m (Airy Ellipsoid)
	λ =	358°02'00.119"E	

* United Kingdom (UK); Airy Ellipsoid

[Revised: 30 September 1988

Table 23.36

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Provisional South American Datum 1956* -

$$
\begin{aligned}
N_m = \; & - 7.203 + 31.131\,U + 18.762\,V + 15.566\,U^2 - 11.261\,UV - 50.515\,V^2 + 8.936\,U^3 + 10.403\,U^2V \\
& + 43.067\,UV^2 - 11.624\,U^4 - 8.754\,U^3V + 84.802\,V^4 - 1.296\,U^5 + 12.535\,U^3V^2 + 1.427\,U^6 \\
& - 1.572\,U^5V - 75.550\,V^6 + 2.753\,U^6V - 41.523\,U^4V^3 - 56.983\,U^3V^4 + 11.012\,U^5V^3 + 7.888\,UV^7 \\
& + 18.358\,V^8 - 4.118\,U^5V^4 + 60.552\,U^4V^5 + 7.512\,U^5V^6 - 3.866\,U^2V^9 - 12.122\,U^6V^7 - 0.007\,U^9V^5 \\
& + 0.073\,U^9V^6 + 0.894\,U^8V^9
\end{aligned}
$$

In the preceding equation:

$U = K\,(\phi + 5)$
$V = K\,(\lambda - 290)$
$K = 0.10471975$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Provisional South American Datum 1956 geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.9 meters; 89 sites involved in the comparison.

Test Case:

Input data for Provisional South American Datum 1956 test point: ϕ = -16°31'33.903"S, λ = 291°50'01.014"E N = -45.39 m (International Ellipsoid)

* Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, Venezuela; International Ellipsoid

Table 23.37

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Puerto Rico Datum* -

$$N_m = -0.194 - 2.762\,V - 30.142\,U^2 - 1.474\,V^2 - 0.072\,V^3 + 37.623\,U^9$$

In the preceding equation:

$U = K\,(\phi - 18)$
$V = K\,(\lambda - 295)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Puerto Rico Datum geoid height (in meters) referenced to the Clarke 1866 Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 20 sites involved in the comparison.

Test Case:

Input data for Puerto Rico Datum test point:	ϕ =	18°22'01.523"N	N = 0.01 m (Clarke 1866 Ellipsoid)
	λ =	292°44'02.548"E	

* Puerto Rico and the Virgin Islands; Clarke 1866 Ellipsoid

Table 23.38

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Qatar National Datum* -

$$N_m = 0.224 - 0.395\,U - 0.455\,V + 0.186\,V^2 - 0.124\,U^4 + 1.909\,U^2V^2 + 0.671\,UV^3 - 0.474\,U^2V^3 - 4.852\,U^7V^8$$

In the preceding equation:

$U = K\,(\phi - 25)$
$V = K\,(\lambda - 51)$
$K = 1.04719754$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Qatar National Datum geoid height (in meters) referenced to International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.0 meter; 7 sites involved in the comparison.

Test Case:

Input data for Qatar National Datum test point:	ϕ =	24°34'55.061"N	N = 0.40 m (International Ellipsoid)
	λ =	50°59'06.940"E	

* Qatar; International Ellipsoid

Table 23.39

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Southwest Base Datum* -

$N_m = -2.321 + 5.039\ U$

In the preceding equation:

$U = K\ (\phi - 38)$
$V = K\ (\lambda - 332)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Southwest Base Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±1.2 meters; 11 sites involved in the comparison.

Test Case:

Input data for Southwest Base Datum test point: ϕ = 38°46'51.568"N, λ = 332°53'52.593"E N = -0.26 m (International Ellipsoid)

* Azores (Faial, Graciosa, Pico, São Jorge, and Terceira Islands); International Ellipsoid

Table 23.40

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Timbalai Datum 1948* -

$$N_m = -1.703 - 6.806\,U - 7.143\,V + 18.663\,U^3 + 23.300\,UV^3 - 13.211\,U^5 - 10.642\,U^4V - 1.909\,V^5 - 36.586\,U^3V^5 - 28.381\,U^3V^7$$

In the preceding equation:

$U = K\,(\phi - 4)$
$V = K\,(\lambda - 114)$
$K = 0.20943951$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Timbalai Datum 1948 geoid height (in meters) referenced to the Everest Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 26 sites involved in the comparison.

Test Case:

Input data for Timbalai Datum 1948 test point:	ϕ =	5°00'39.333"N	N = -4.49 m (Everest Ellipsoid)
	λ =	115°02'46.480"E	

* Brunei and East Malaysia (Sarawak and Sabah); Everest Ellipsoid

[Revised: 30 September 1988]

Table 23.41

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights
- Wake-Eniwetok Datum 1960* -

$$N_m = -4.879 + 0.201\,U - 0.096\,UV - 0.041\,V^4 - 1.233\,U^6 + 0.017\,U^2V^4 + 0.532\,U^8 + 0.365\,U^6V^3 - 0.009\,U^8V^6$$

In the preceding equation:

$U = K\,(\phi - 9)$
$V = K\,(\lambda - 167)$
$K = 2.09439507$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Wake-Eniwetok Datum 1960 geoid height (in meters) referenced to Hough Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ± 0.0 meter; 6 sites involved in the comparison.

Test Case:

Input data for Wake-Eniwetok Datum 1960 test point:	ϕ =	8°43'12.587"N	N = -5.10 m (Hough Ellipsoid)
	λ =	167°44'13.400"E	

* Kwajalein Atoll Area Only; Hough Ellipsoid

Table 23.42

Multiple Regression Equation for DMA-Developed
Local Geodetic System Geoid Heights
- Zanderij Datum* -

$$N_m = -0.781 + 7.775\,U + 3.048\,V + 2.838\,U^2 + 2.604\,UV + 3.077\,V^2 + 1.509\,U^3 + 1.997\,UV^2 + 0.833\,V^3 + 1.105\,U^4V + 0.435\,U^5V$$

In the preceding equation:

$U = K\,(\phi - 5)$
$V = K\,(\lambda - 305)$
$K = 0.52359877$
ϕ = geodetic latitude, local geodetic system, in degrees and decimal part of a degree; positive north (0° to 90°), negative south (0° to -90°)
λ = geodetic longitude, local geodetic system, in degrees and decimal part of a degree; positive east from 0° to 360°
N = DMA-developed Zanderij Datum geoid height (in meters) referenced to the International Ellipsoid

The preceding equation reproduced the geoid heights from which it was generated to a root-mean-square (RMS) difference of ±0.3 meter; 22 sites involved in the comparison.

Test Case:

Input data for Zanderij Datum test point:	ϕ =	5°27'09.451"N	N = 0.89 m (International Ellipsoid)
	λ =	304°47'47.486"E	

* Surinam; International Ellipsoid

[Revised: 30 September 1988]

Table 23.43

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights* - Remaining Local Geodetic Systems

Local Geodetic System	Geoid Height (Meters)	Reference Ellipsoid	Local Geodetic System	Geoid Height (Meters)	Reference Ellipsoid
ADINDAN			ASTRONOMIC STATION 1952		
Mali	**	Clarke 1880	Marcus Island	-3	International
Senegal	**	Clarke 1880			
AFGOOYE			BELLEVUE (IGN)		
Somalia	**	Krassovsky	Efate and Erromango Islands (New Hebrides Islands)	-4	International
AIN EL ABD 1970			BERMUDA 1957		
Bahrain Island	1	International	Bermuda Islands	-4	Clarke 1866
ANNA 1 ASTRO 1965			CHATHAM 1971		
Cocos Islands	-3	Australian National	Chatham Island	3	International
ASCENSION ISLAND 1958			DOS 1968		
Ascension Island	-2	International	Gizo Island (New Georgia Islands)	0	International
ASTRO BEACON "E"			EASTER ISLAND 1967		
Iwo Jima Island	-8	International	Easter Island	0	International
ASTRO B4 SOROL ATOLL			EUROPEAN DATUM 1950		
Tern Island	-7	International	Sardinia	-2	International
			Sicily	-1	International
ASTRO DOS 71/4			GANDAJIKA BASE		
St. Helena Island	-3	International	Republic of Maldives	1	International

* For use throughout the areal extent of the local geodetic system and/or geographical area listed; supplements Table 23.1 through Table 23.42

** Time constraints prevented inclusion of DMA-developed local geodetic system geoid heights in this form for these datums or areas. If such data is required, contact DMA (see PREFACE).

[Revised: 30 September 1988]

Table 23.43 (Cont'd)

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights* - Remaining Local Geodetic Systems

Local Geodetic System	Geoid Height (Meters)	Reference Ellipsoid	Local Geodetic System	Geoid Height (Meters)	Reference Ellipsoid
GUX 1 ASTRO Guadalcanal Island	-1	International	MAHE 1971 Mahe Island	-1	Clarke 1880
HONG KONG 1963 Hong Kong	1	International	MARCO ASTRO Salvage Islands	-4	International
INDIAN Bangladesh, India, and Nepal	**	Everest	MASSAWA Eritrea (Ethiopia)	**	Bessel 1841
ISTS 073 ASTRO 1969 Diego Garcia	-2	International	MIDWAY ASTRO 1961 Midway Island	-6	International
JOHNSTON ISLAND 1961 Johnston Island	-4	International	NAHRWAN Saudi Arabia	**	Clarke 1880
KERGUELEN ISLAND Kerguelen Island	0	International	NAPARIMA, BWI Trinidad and Tobago	3	International
L.C.5 ASTRO Cayman Brac Island	-2	Clarke 1866	NAD 27 Greenland (Hayes Peninsula)	**	Clarke 1866
LUZON Mindanao Island	**	Clarke 1866	OBSERVATORIO 1966 Corvo and Flores Islands (Azores)	2	International

* For use throughout the areal extent of the local geodetic system and/or geographical area listed; supplements Table 23.1 through Table 23.42.

** Time constraints prevented inclusion of DMA-developed local geodetic system geoid heights in this form for these datums or areas. If such data is required, contact DMA (see PREFACE).

Table 23.43 (Cont'd)

Multiple Regression Equations for DMA-Developed
Local Geodetic System Geoid Heights* - Remaining Local Geodetic Systems

Local Geodetic System	Geoid Height (Meters)	Reference Ellipsoid	Local Geodetic System	Geoid Height (Meters)	Reference Ellipsoid
PICO DE LAS NIEVES Canary Islands	-6	International	SÃO BRAZ São Miguel, Santa Maria Islands (Azores)	-1	International
PITCAIRN ASTRO 1967 Pitcairn Island	-3	International	SAPPER HILL 1943 East Falkland Island	1	International
PROVISIONAL SOUTH CHILEAN 1963 South Chile (Near 53°S)	0	International	SCHWARZECK Namibia	**	Bessel 1841
QORNOQ South Greenland	6*** 23****	International	SOUTH ASIA Singapore	0	Modified Fischer 1960
REUNION Mascarene Island	-6	International	SOUTHEAST BASE Porto Santo and Madeira Islands	-3	International
ROME 1940 Sardinia Island	3	International	TRISTAN ASTRO 1968 Tristan da Cunha	2	International
SANTO (DOS) Espirito Santo Island	-4	International	VITI LEVU 1916 Viti Levu Island (Fiji Islands)	0	Clarke 1880

* For use throughout the areal extent of the local geodetic system and/or geographical area listed; supplements Table 23.1 through Table 23.42

** Time constraints prevented inclusion of DMA-developed local geodetic system geoid heights in this form for these datums or areas. If such data is required, contact DMA (see PREFACE).

*** Vicinity of 61°30'N, 318°E

**** Vicinity of 67°N, 309°E

SECTION 24

SOLVING DIRECTLY
FOR
WGS 84 COORDINATES

Table 24.1

Procedure for Solving Directly for WGS 84 Coordinates*

1. Acquire Doppler Data (35 or More Passes) from Each Site to be Positioned.

2. Acquire Precise Ephemerides for "Tracked" Navy Navigation Satellite System (NNSS) Satellites from DMA. The Precise Ephemerides are Based on:

   a. Defining Parameters of WGS 84 Ellipsoid

   b. WGS 84 EGM (n=m=41)

   c. WGS 84 Coordinates for Doppler Tracking Network (TRANET) Stations Used in the Generation of the Precise Ephemerides. (These Station Coordinates, Determined When Placing the NNSS on WGS 84, are Held Fixed.)

3. Perform Satellite Point Positioning Solution (Using Data From 1, Above), Holding Precise Ephemerides (From 2, Above) Fixed Within Estimated Error Bounds, to Directly Obtain Doppler-Derived WGS 84 Coordinates for Site of Interest.

* It is anticipated that current usage of NNSS Satellites will give way to NAVSTAR GPS Satellites and associated tracking data as the latter System nears full operational capability.

Table 24.2

WGS 84 Coordinates
Solved for Directly in WGS 84
- Comments -

1. The accuracy (one sigma) of WGS 84 coordinates directly determined in WGS 84 by Doppler Satellite Point Positioning utilizing NNSS Satellites, their respective precise ephemerides, and ground-based Doppler Satellite tracking data acquired in the static mode [2; Sections 7.2.1 and 9.2] is in geodetic latitude, geodetic longitude, and geodetic height:

$$\sigma_{\phi} \text{ (WGS 84)} = \pm 1 \text{ m}$$
$$\sigma_{\lambda} \text{ (WGS 84)} = \pm 1 \text{ m}$$
$$\sigma_{H} \text{ (WGS 84)} = \pm 1 \text{ to } \pm 2 \text{ m.}$$

A similar Satellite Point Positioning capability utilizing NAVSTAR GPS Satellites is currently under development by DMA.

2. Organizations desiring directly solved for WGS 84 coordinates at special locations such as test range sensor sites, etc., for reasons of accuracy and/or confidence, should make their requirements known through appropriate Service channels to the address provided in the PREFACE.

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SECTION 25

CONVERSION OF WGS 72 COORDINATES
TO
WGS 84 COORDINATES

Table 25.1

Conversion of WGS 72 Coordinates
to WGS 84 Coordinates
- Comments -

1. Formulas (General Form)

$$\phi_{WGS\ 84} = \phi_{WGS\ 72} + \Delta\phi$$

$$\lambda_{WGS\ 84} = \lambda_{WGS\ 72} + \Delta\lambda$$

$$H_{WGS\ 84} = H_{WGS\ 72} + \Delta H$$

[ϕ = Geodetic Latitude, λ = Geodetic Longitude, H = Geodetic Height]

2. WGS 84 Coordinates Will Differ From WGS 72 Coordinates Due To:

- Shift in Coordinate System Origin
- Change in Longitude Reference
- Change in Scale
- Changes in Ellipsoid Size (a) and Shape (f)
  (a = Semimajor Axis, f = Flattening)

[See Figures 25.1, 25.2, 25.3, 25.4, and 25.5]

3. NOTE:

At non-Doppler sites, this method of obtaining WGS 84 coordinates (Table 25.1) should generally only be used if localized Local Geodetic System-to-WGS 84 Datum Shifts are not available or if WGS 84 Coordinates cannot be solved for directly in WGS 84 using Satellite Point Positioning and ground-based satellite tracking data. [Also, see Section 11, Section 24, Section 26 (Figures 26.1 - 26.30), and Section 27 (Table 27.1, Figures 27.1 - 27.21) of this report and Sections 7.2.3 and 9.3 of Reference 2.]

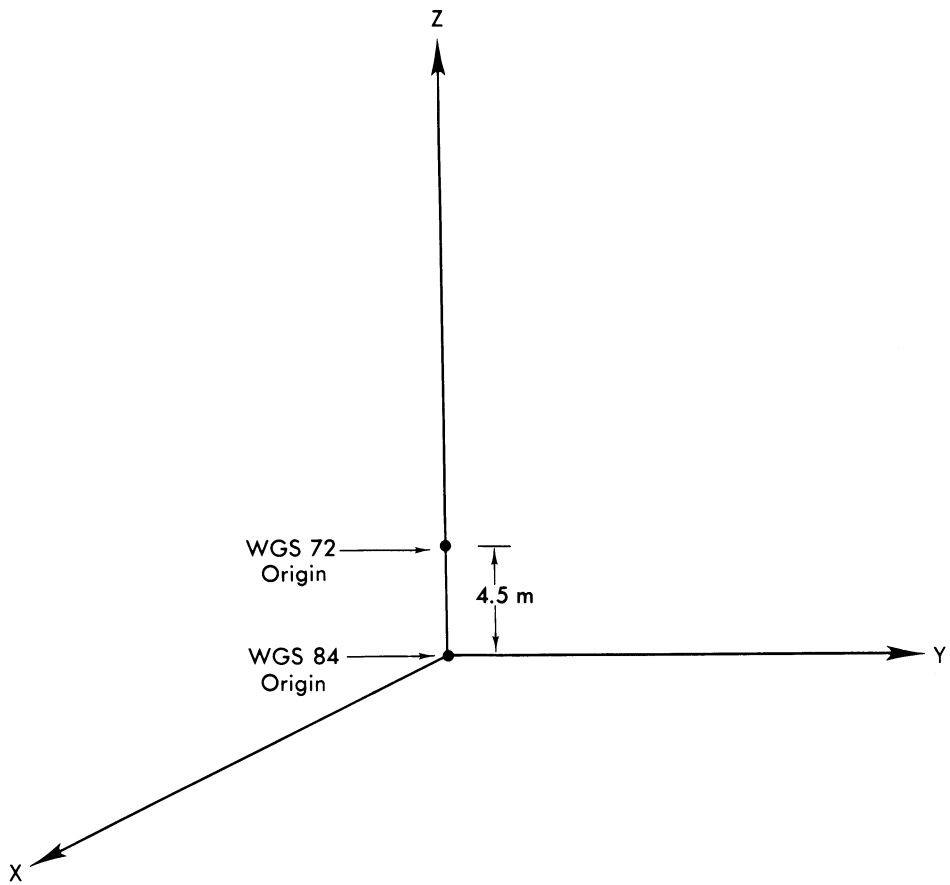


Figure 25.1. Difference Between WGS 72 and WGS 84 Reference Frame Origins

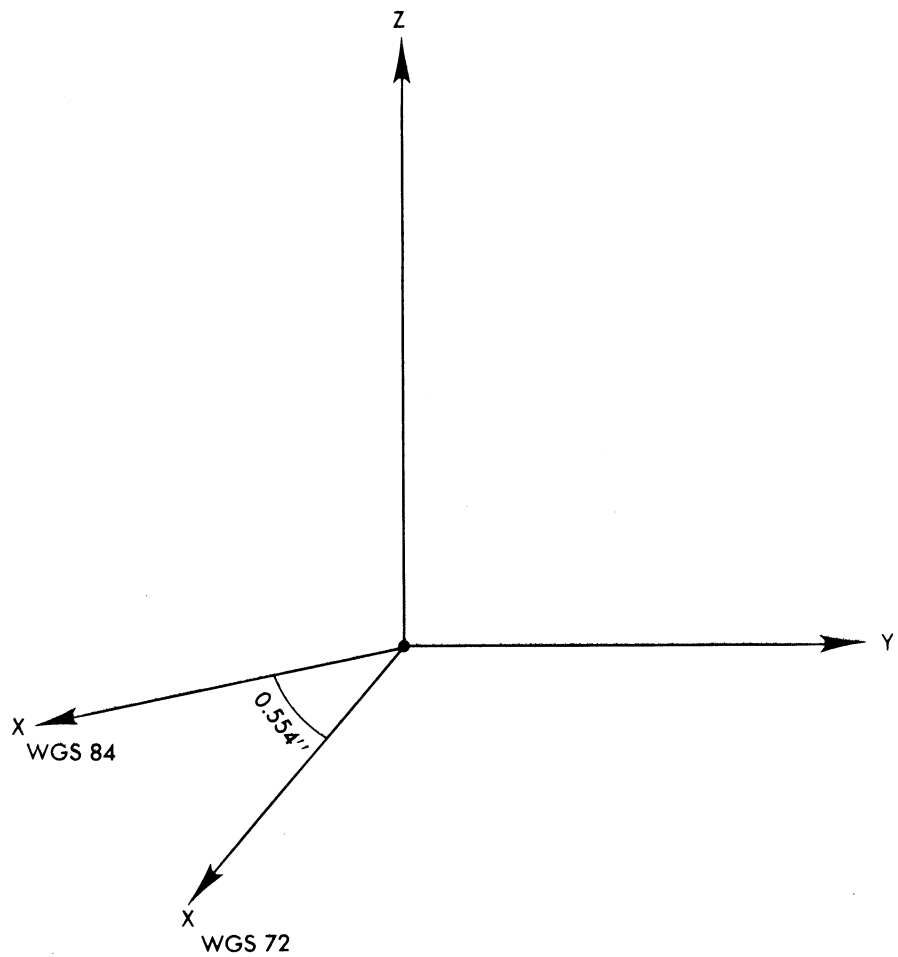


Figure 25.2. Difference Between WGS 72 and WGS 84 Longitude References (X-Axes)

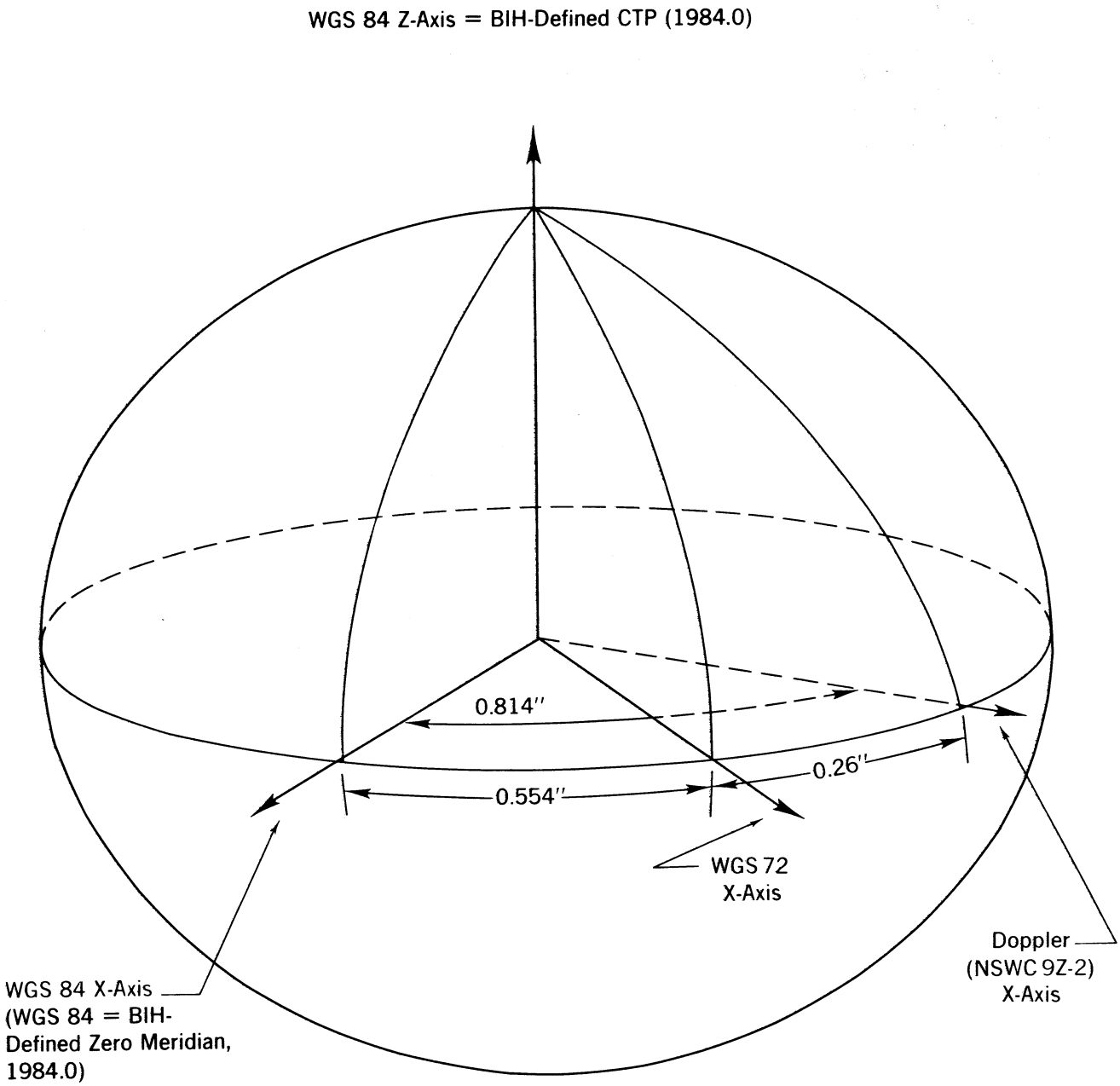
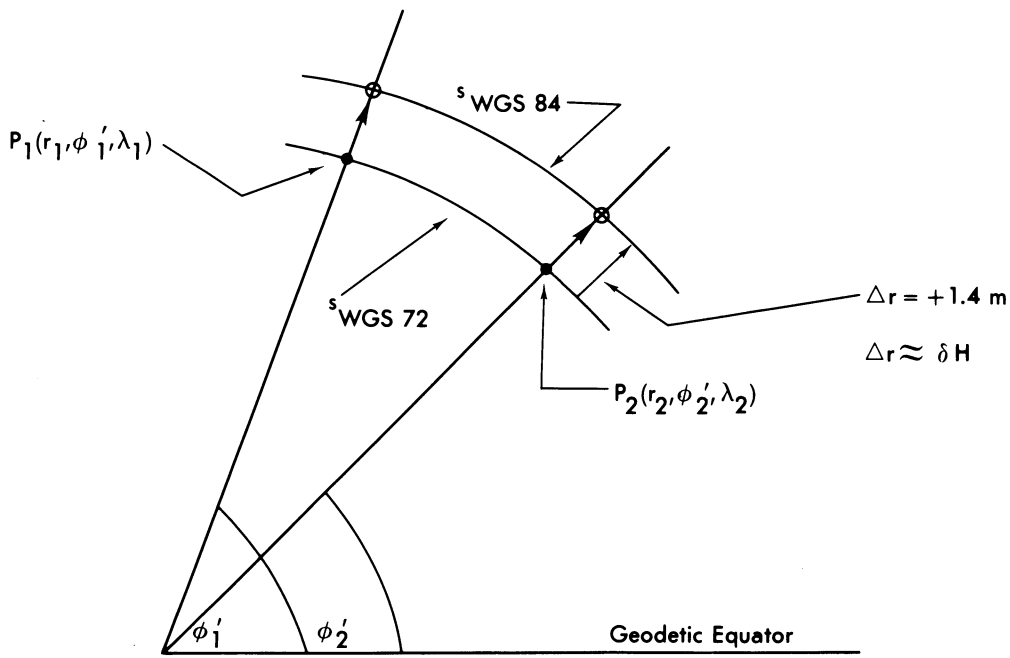


Figure 25.3. Reference Longitude Relationships: Doppler (NSWC 9Z-2), WGS 72, and WGS 84 = BIH-Defined Zero Meridians

$({}^{s}\text{WGS 72} < {}^{s}\text{WGS 84})$

s = distance
r = radius vector
ϕ' = geocentric latitude
λ = geocentric (geodetic) longitude
H = geodetic height



(See Table 25.2.)

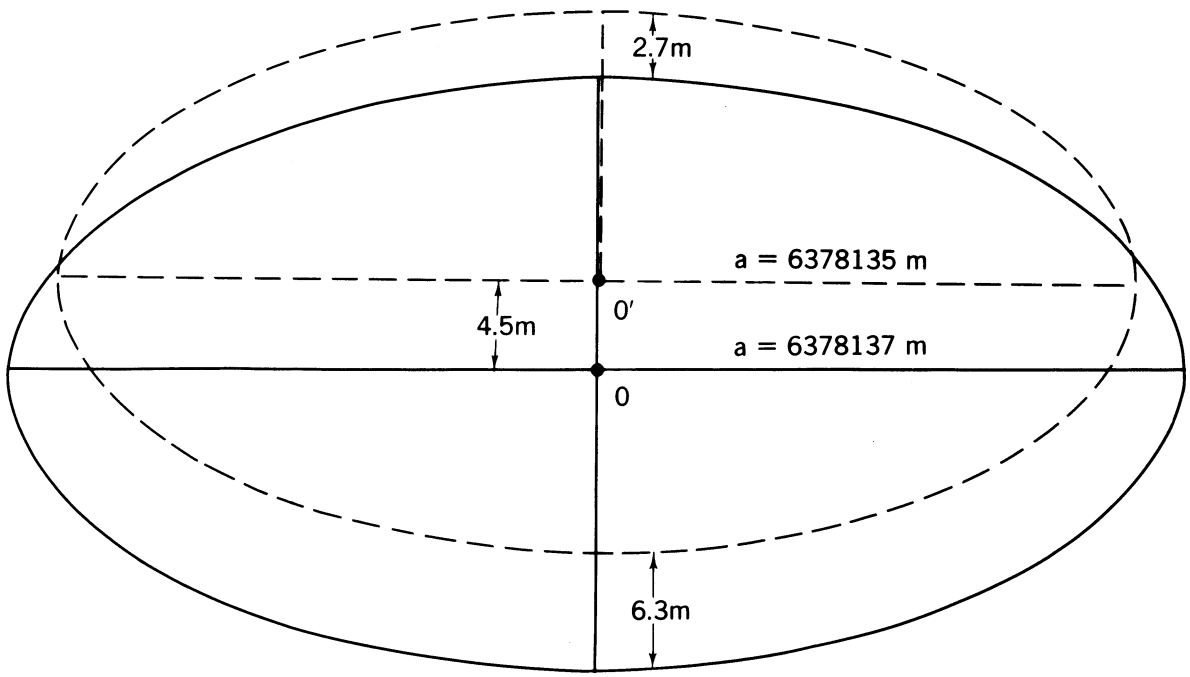
Figure 25.4. Differences Between WGS 84 and WGS 72 Distances and Geodetic Heights (Effect of Scale Change)

WGS 84

a = 6378137m
b = 6356752.3142m
f = 1/298.257223563
(0.00335281066474)

WGS 72

a = 6378135m
b = 6356750.5m
f = 1/298.26
(0.00335277945417)



0 = Origin of WGS 84 Ellipsoid = Earth's Center of Mass

0′ = Origin of WGS 72 Ellipsoid = Earth's Center of Mass (as Known in 1972)

Figure 25.5. WGS 84 and WGS 72 Ellipsoid Differences (Size, Shape)

Table 25.2

Formulas and Parameters
to Transform WGS 72 Coordinates
to WGS 84 Coordinates

Formulas	$\Delta\phi'' = (4.5 \cos \phi) / (a \sin 1'') + (\Delta f \sin 2\phi) / (\sin 1'')$ $\Delta\lambda'' = 0.554$ $\Delta H_m = 4.5 \sin \phi + a\ \Delta f \sin^2\phi - \Delta a + \Delta r$
Parameters	$\Delta f = 0.3121057 \times 10^{-7}$ $a = 6378135$ m $\Delta a = 2.0$ m $\Delta r = 1.4$ m (See Figure 25.4.)
Instructions	To Obtain WGS 84 Coordinates, Add the $\Delta\phi$, $\Delta\lambda$, ΔH Changes Calculated Using WGS 72 Coordinates to the WGS 72 Coordinates (ϕ, λ, and H, Respectively). (Table 25.3 Entries May be Used as Test Points.) Latitude is Positive North and Longitude is Positive East (0° to 360°).

Table 25.3

Difference Between WGS 84
and WGS 72 Geodetic Coordinates*

Degrees	Difference (Meters)		
	Latitude	Longitude	Height
90 N	0.0	0.0	4.1
85	0.4	1.5	4.1
80	0.8	3.0	4.0
75	1.3	4.4	3.9
70	1.7	5.9	3.8
65	2.1	7.2	3.6
60	2.4	8.6	3.4
55	2.8	9.8	3.2
50	3.1	11.0	3.0
45	3.4	12.1	2.7
40	3.6	13.1	2.4
35	3.9	14.0	2.0
30	4.1	14.8	1.7
25	4.2	15.5	1.3
20	4.4	16.1	1.0
15	4.4	16.5	0.6
10	4.5	16.9	0.2
5 N	4.5	17.1	-0.2
0	4.5	17.1	-0.6
5 S	4.4	17.1	-1.0
10	4.4	16.9	-1.4
15	4.2	16.5	-1.8
20	4.1	16.1	-2.1
25	3.9	15.5	-2.5
30	3.7	14.8	-2.8
35	3.5	14.0	-3.1
40	3.3	13.1	-3.4
45	3.0	12.1	-3.7
50	2.7	11.0	-3.9
55	2.4	9.8	-4.2
60	2.1	8.6	-4.3
65	1.7	7.2	-4.5
70	1.4	5.9	-4.7
75	1.1	4.4	-4.8
80	0.7	3.0	-4.8
85	0.4	1.5	-4.9
90 S	0.0	0.0	-4.9

*Applies only when proceeding directly from WGS 72 Coordinates to WGS 84 Coordinates; does not contain the effect of the WGS 84 Earth Gravitational Model and Geoid, nor the effect of Local Geodetic System-to-WGS 84 Datum Shifts being better than Local Geodetic System-to-WGS 72 Datum Shifts. Results in this Table are based on formulas and input data from Table 25.2. (Also, see Table 6.1.)

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SECTION 26

MAXIMUM COORDINATE DIFFERENCES

- WGS 84 MINUS WGS 72 -

[$\Delta\phi$, $\Delta\lambda$, ΔH CONTOUR CHARTS]*

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* FOR THE PRINCIPAL LOCAL GEODETIC SYSTEMS HAVING LOCAL GEODETIC SYSTEM-TO-WGS 72 DATUM SHIFTS [4]. ALSO, WITH RESPECT TO THE MAXIMUM COORDINATE DIFFERENCES: WGS 84 GEODETIC LATITUDES AND GEODETIC LONGITUDES DETERMINED VIA NSWC 9Z-2 TO WGS 84 TRANSFORMATION; WGS 84 GEODETIC HEIGHTS FORMED USING WGS 84 GEOID HEIGHTS AND HEIGHT ABOVE MEAN SEA LEVEL VALUES; WGS 72 COORDINATES DETERMINED USING LOCAL GEODETIC SYSTEM-TO-WGS 72 MEAN DATUM SHIFTS; WGS 72 GEODETIC HEIGHTS REFLECT USE OF LOCAL GEODETIC SYSTEM GEODETIC HEIGHTS FORMED USING DMA-DEVELOPED LOCAL GEODETIC SYSTEM GEOID HEIGHTS AND HEIGHT-ABOVE-MEAN SEA LEVEL VALUES (THE "MAXIMUM" GEODETIC HEIGHT DIFFERENCES RECORDED HEREIN WOULD, OF COURSE, BE LARGER IF LOCAL GEODETIC SYSTEM GEOID HEIGHTS WERE MISSING OR ASSUMED ZERO). CAUTION: THESE MAXIMUM COORDINATE DIFFERENCE CONTOUR CHARTS ARE PROVIDED FOR ILLUSTRATIVE PURPOSES ONLY; DO NOT USE TO DERIVE A TRANSFORMATION FROM WGS 72-TO-WGS 84.

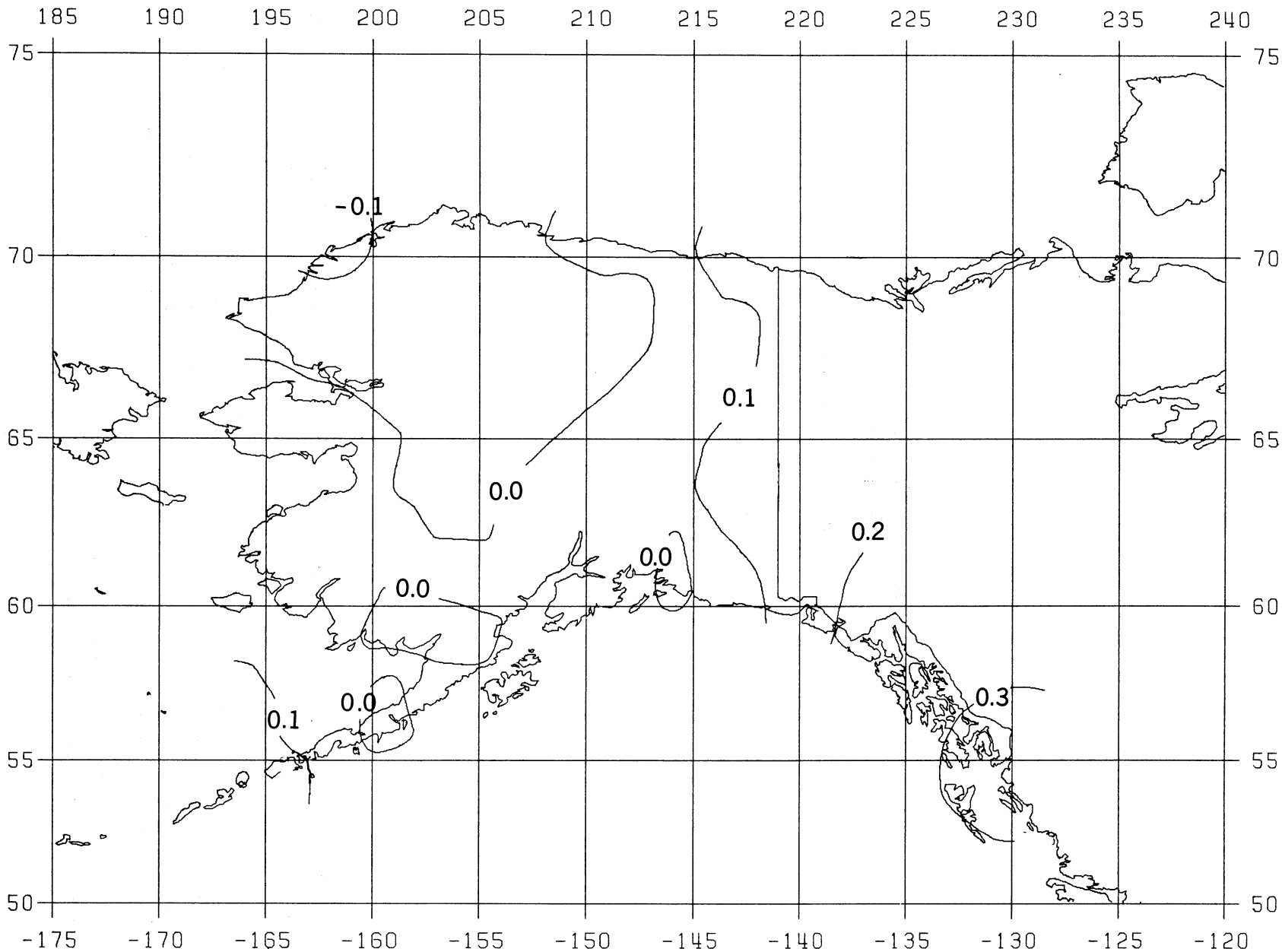

Figure 26.1. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, Alaska) - (Units = 0.1 Arc Second)

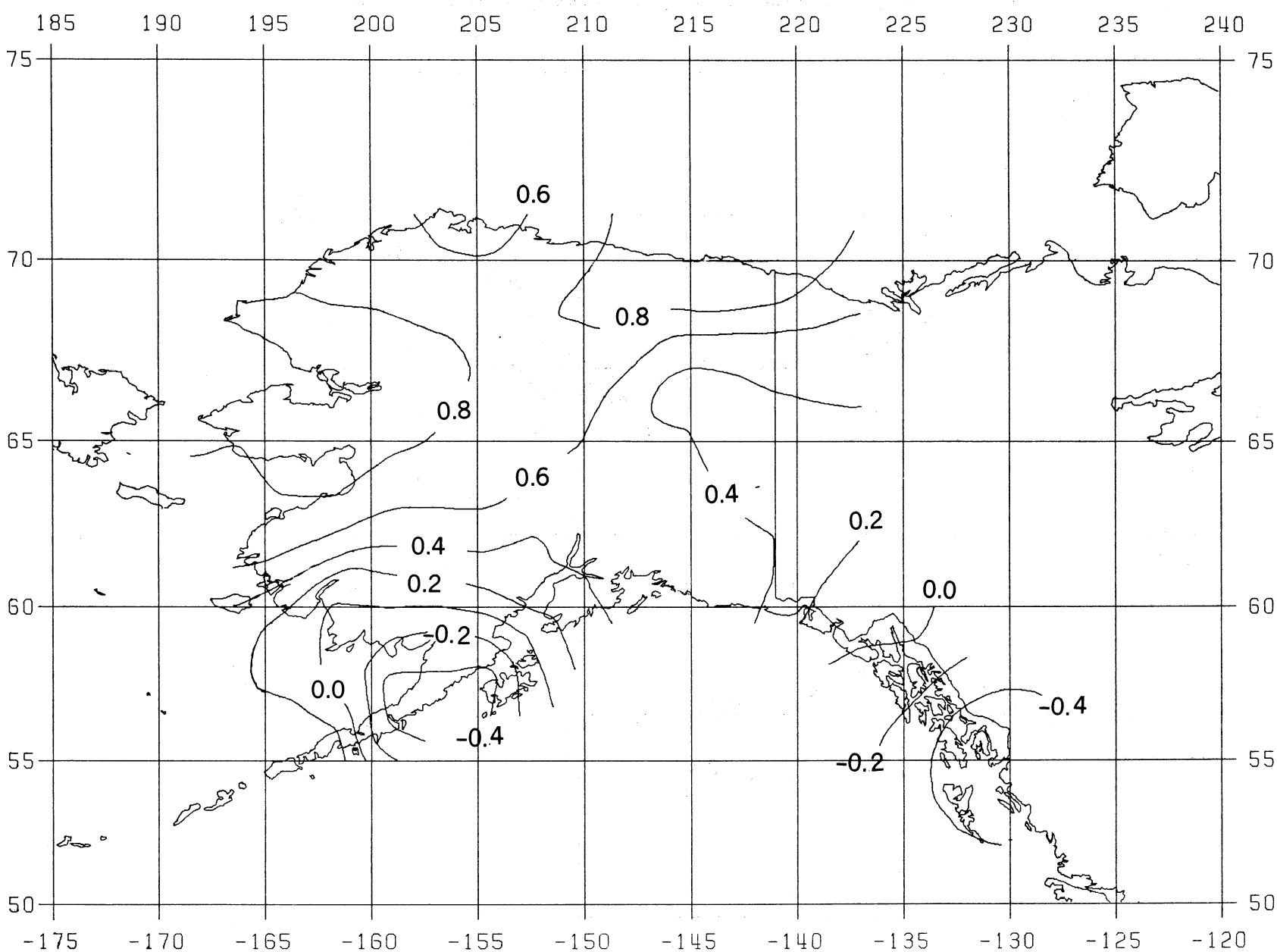

Figure 26.2. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, Alaska) - (Units = 0.2 Arc Second)

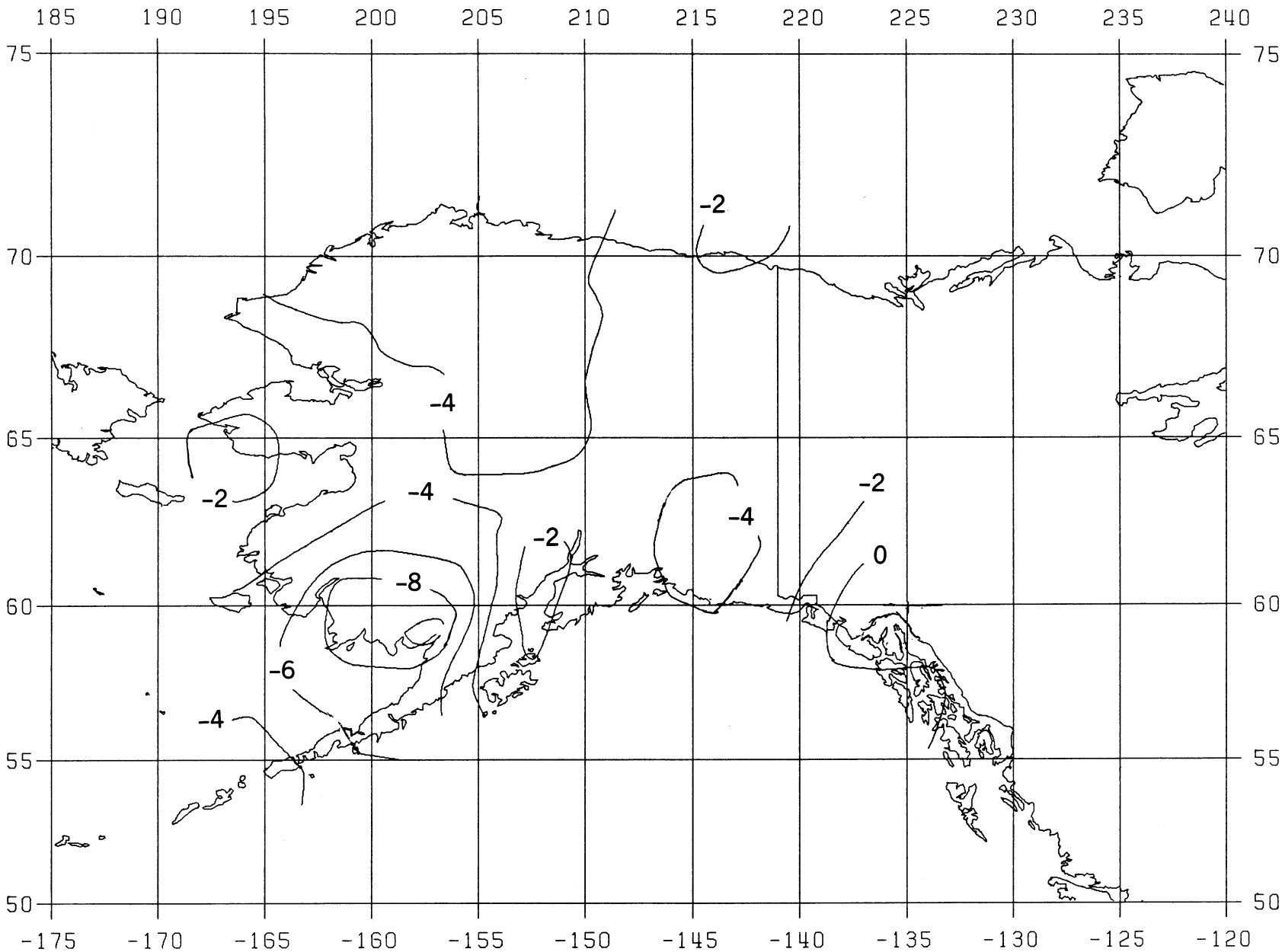

Figure 26.3. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, Alaska) - (Units = 2 Meters)

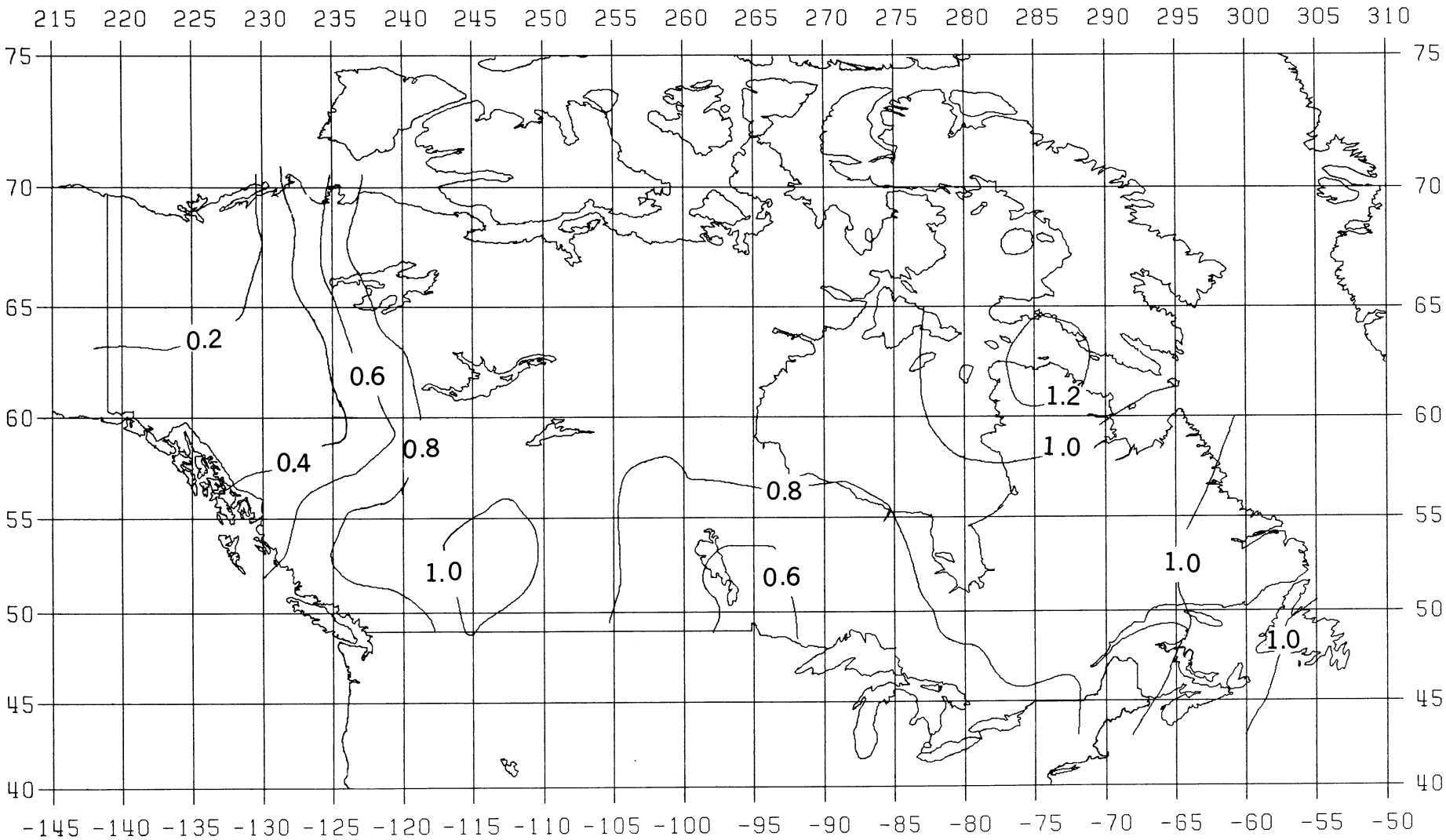

Figure 26.4. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, Canada) - (Units = 0.2 Arc Second)

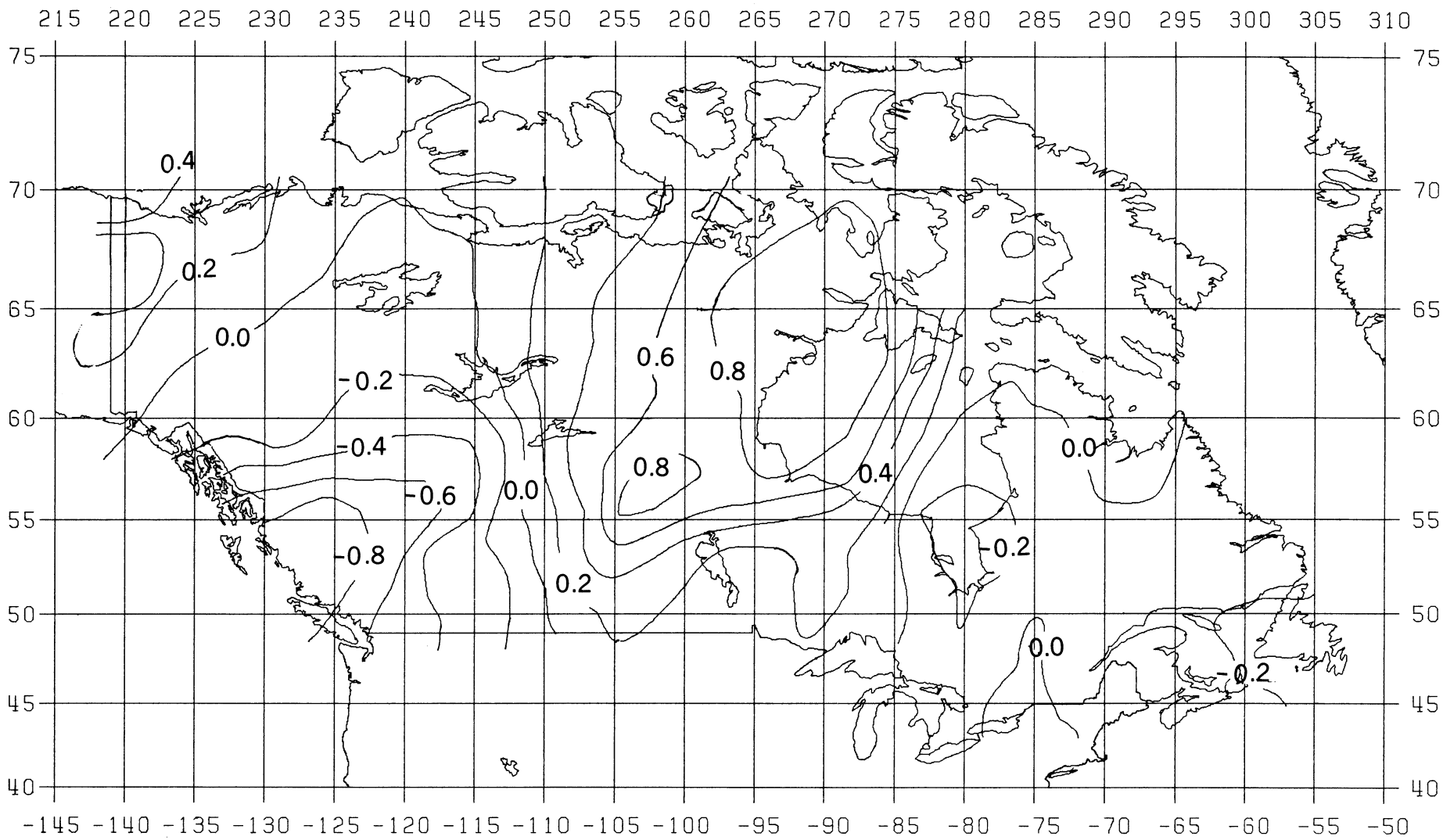

Figure 26.5. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, Canada) - (Units = 0.2 Arc Second)

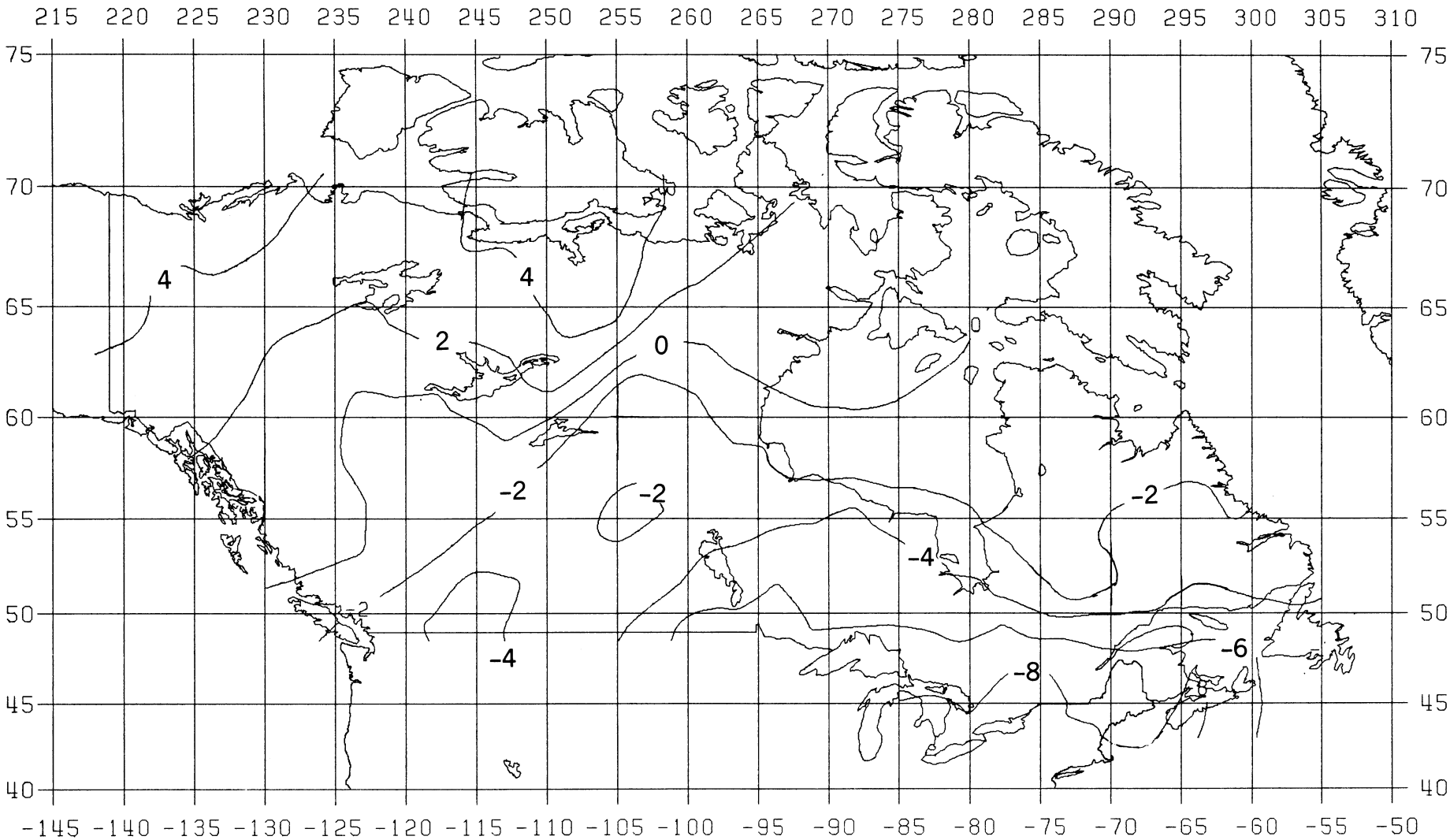

Figure 26.6. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, Canada) - (Units = 2 Meters)

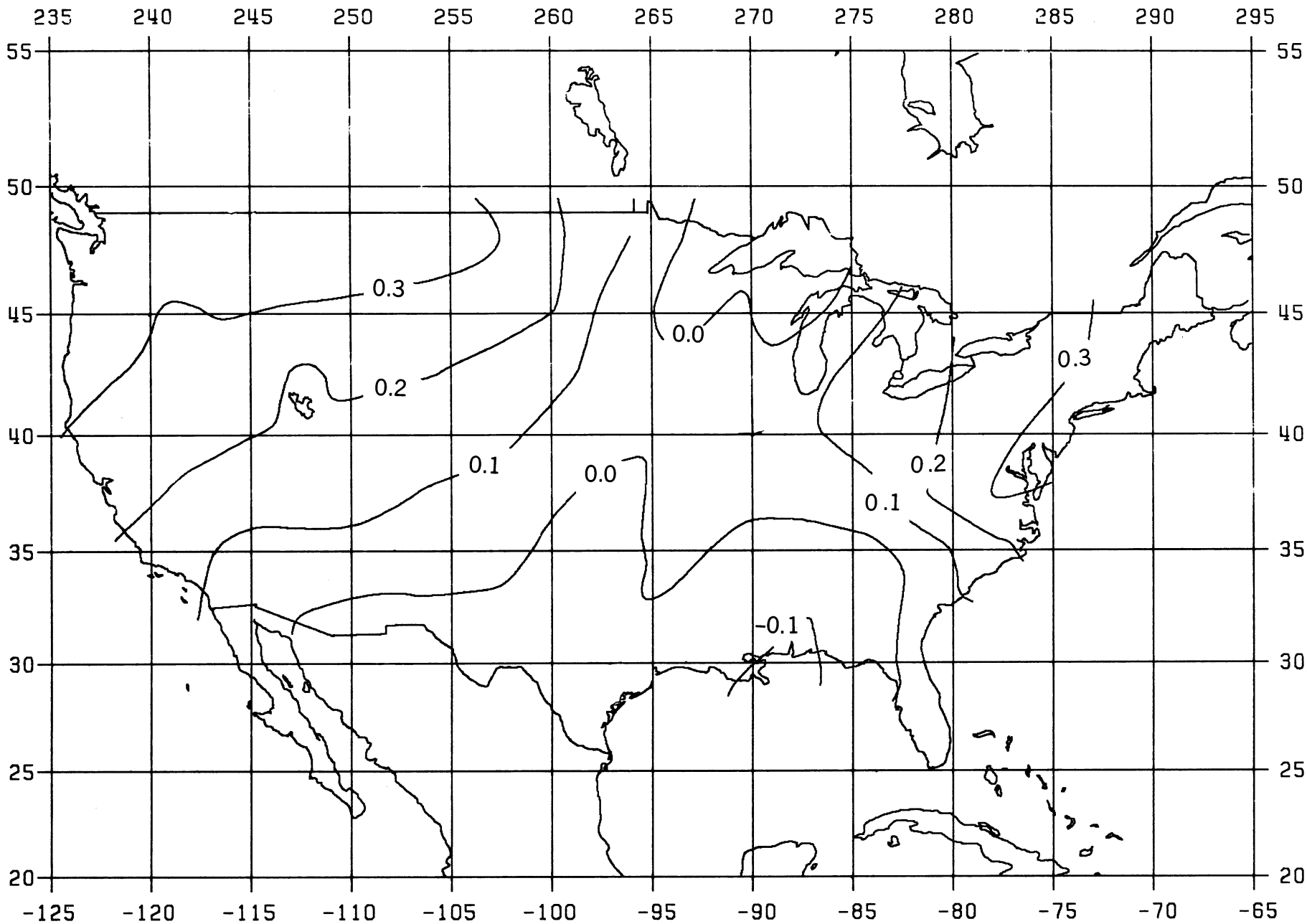

Figure 26.7. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, CONUS)-(Units = 0.1 Arc Second)

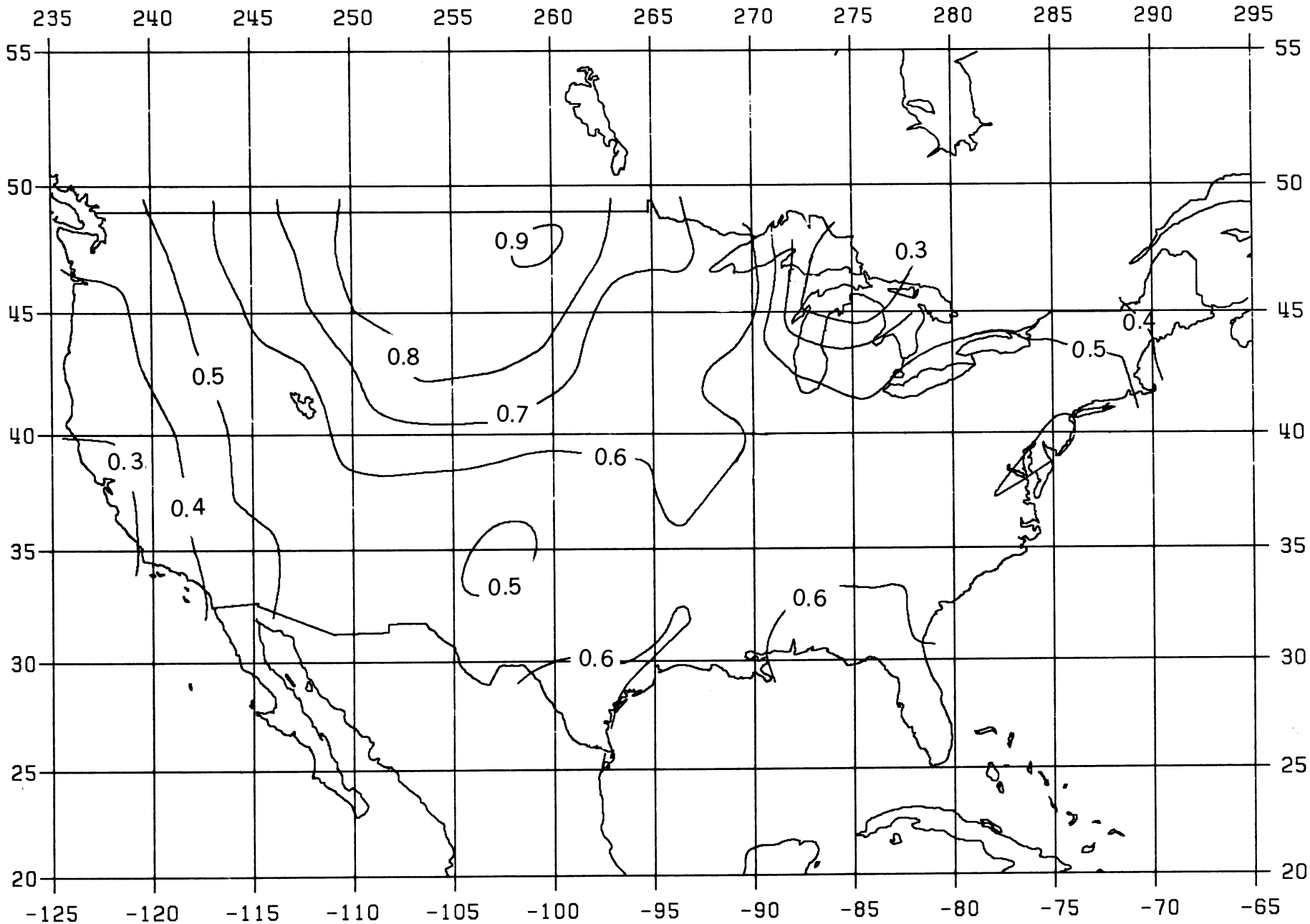

Figure 26.8. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, CONUS) - (Units = 0.1 Arc Second)

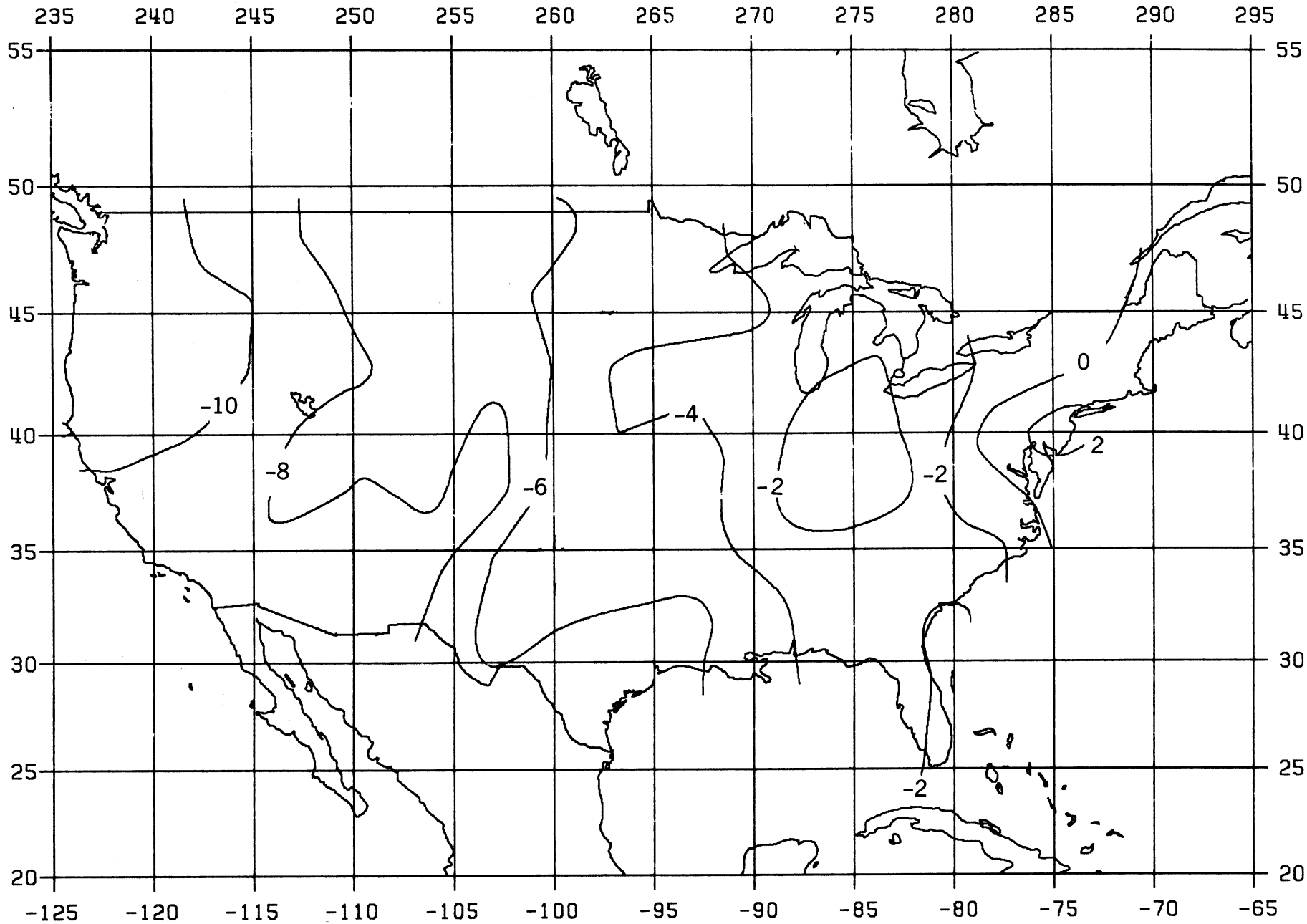

Figure 26.9. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (NAD 27 Area, CONUS)-(Units = 2 Meters)

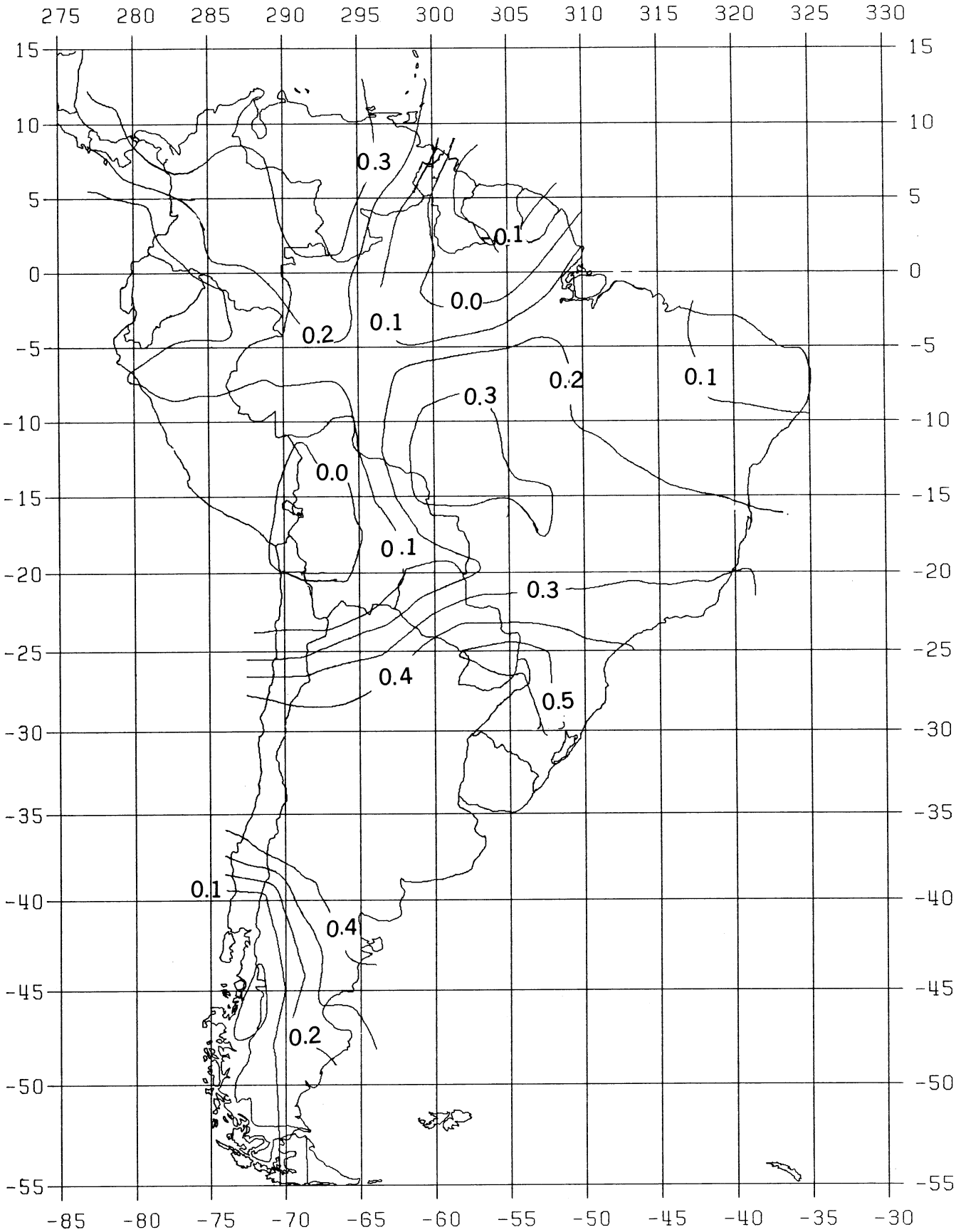

Figure 26.10. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (SAD 69 Area)–(Units = 0.1 Arc Second)

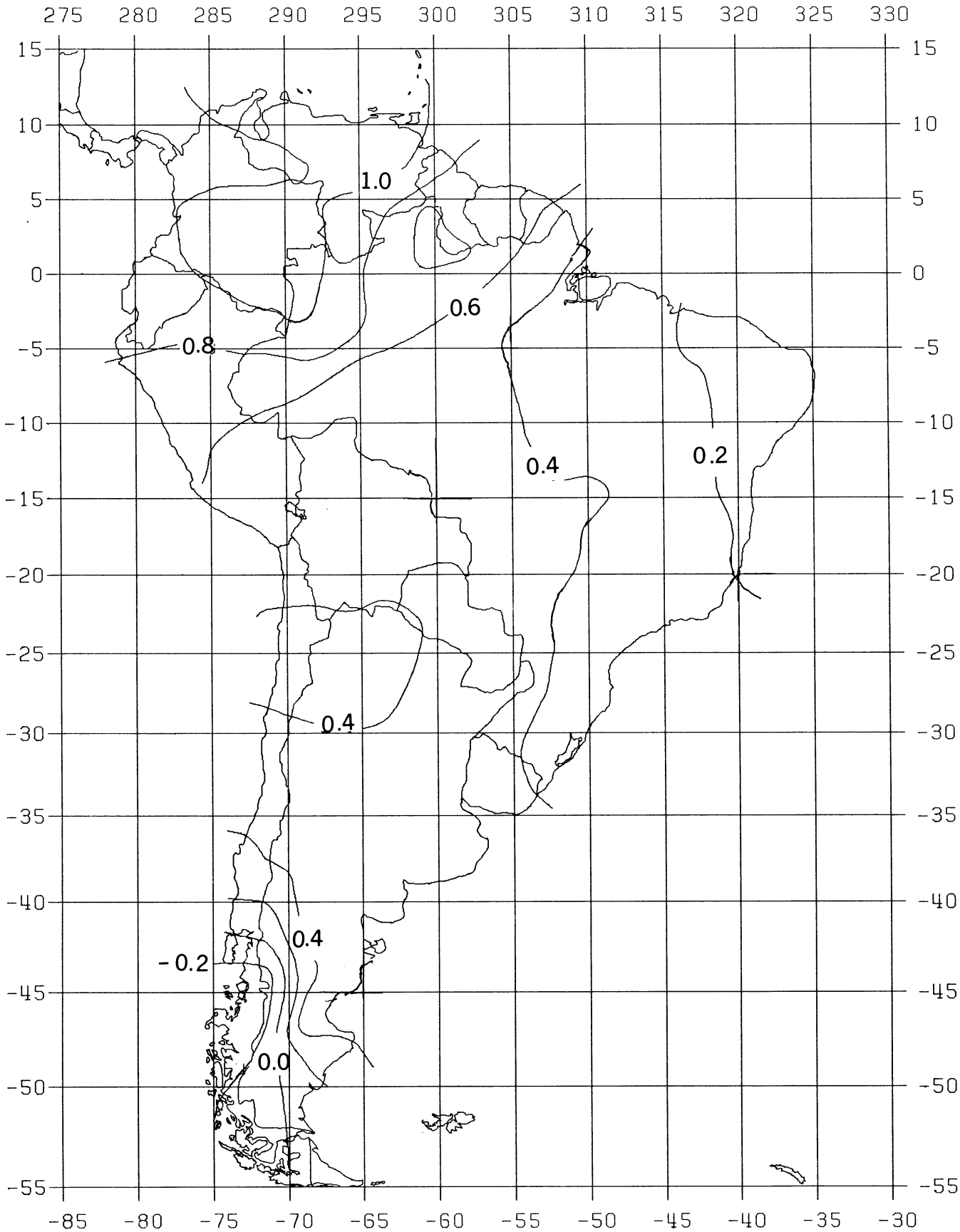

Figure 26.11. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (SAD 69 Area)– (Units = 0.2 Arc Second)

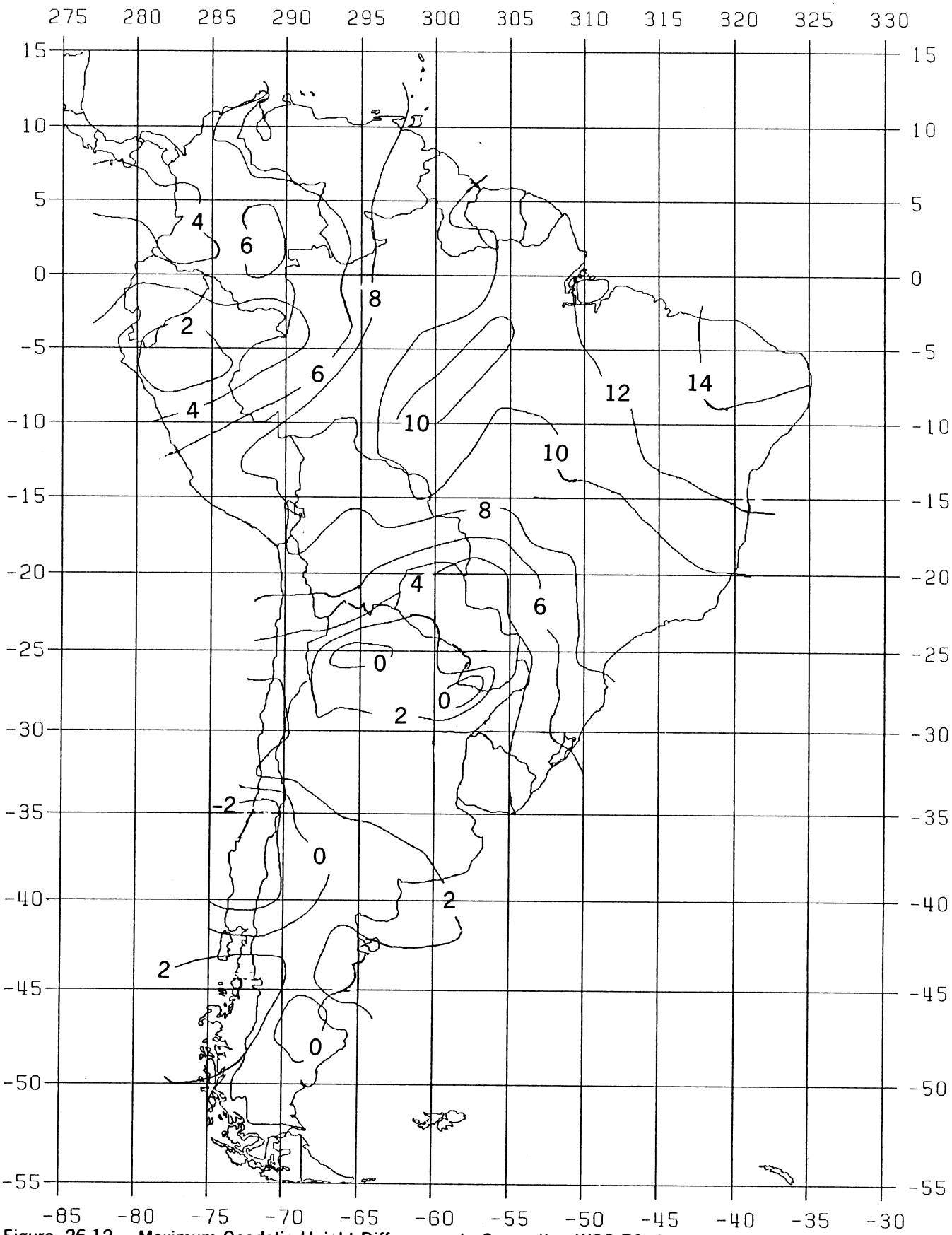

Figure 26.12. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (SAD 69 Area) -(Units = 2 Meters)

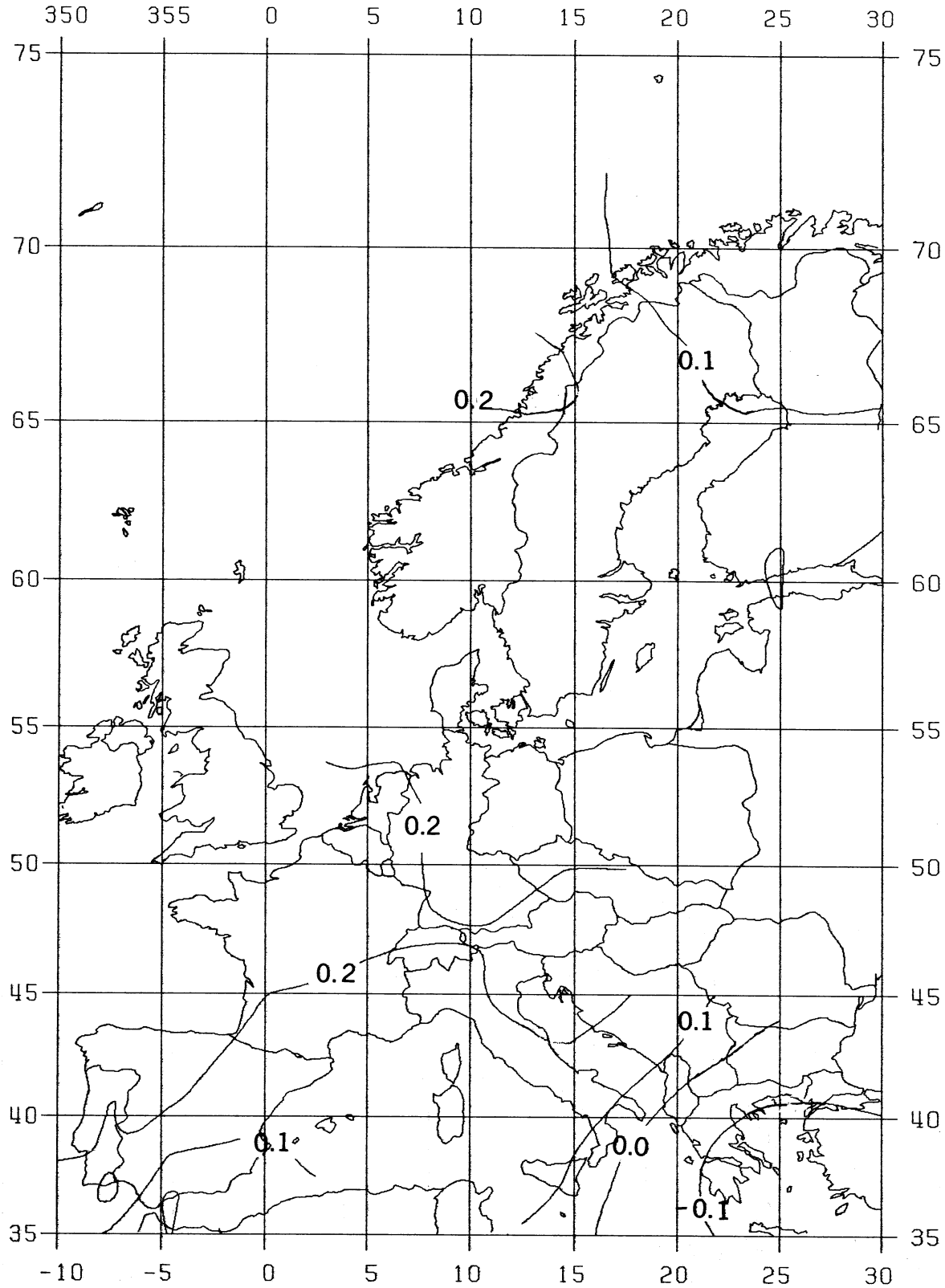

Figure 26.13. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (ED 50 Area, Western Europe) - (Units = 0.1 Arc Second)

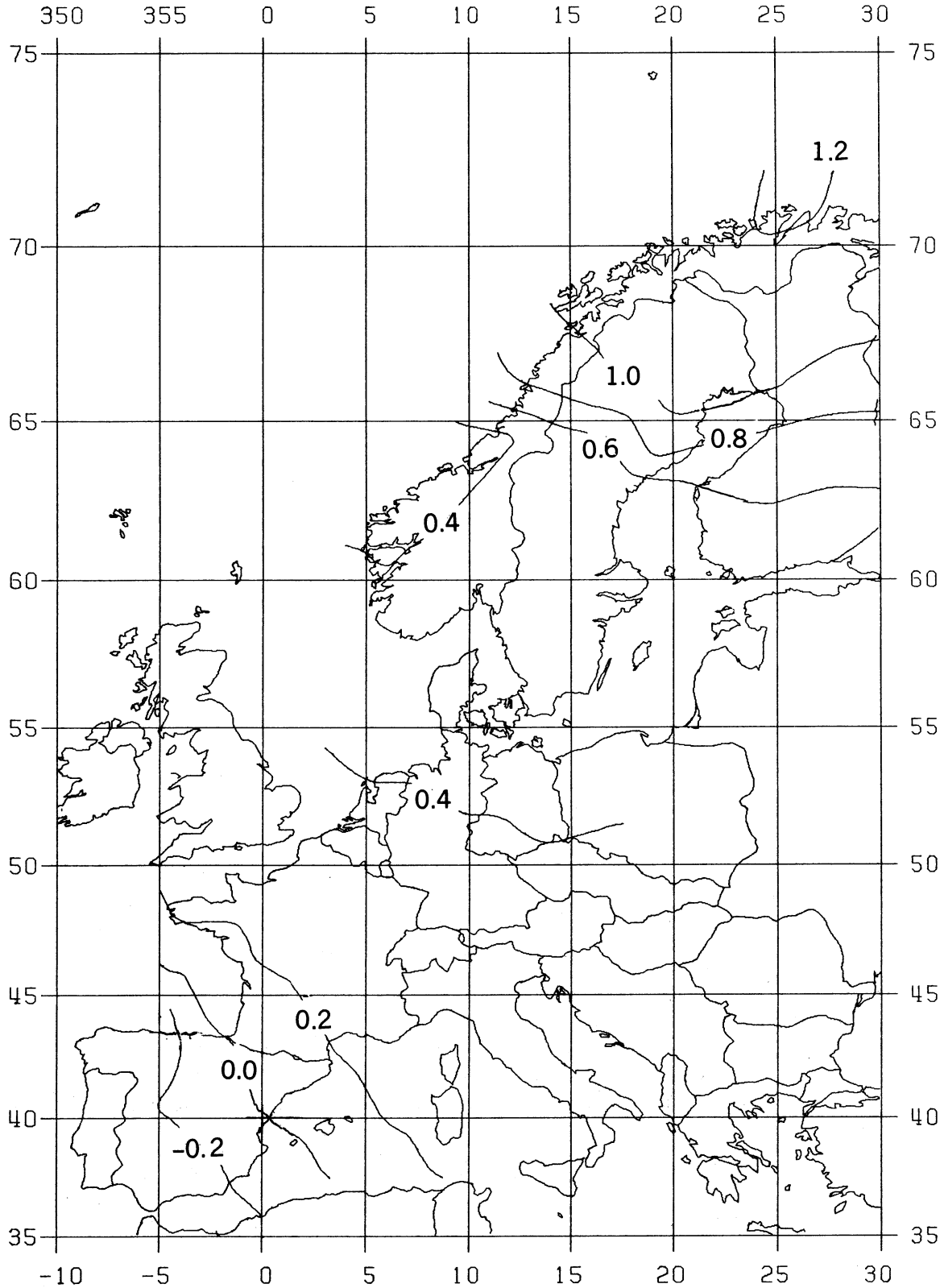

Figure 26.14. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (ED 50 Area, Western Europe) - (Units = 0.2 Arc Second)

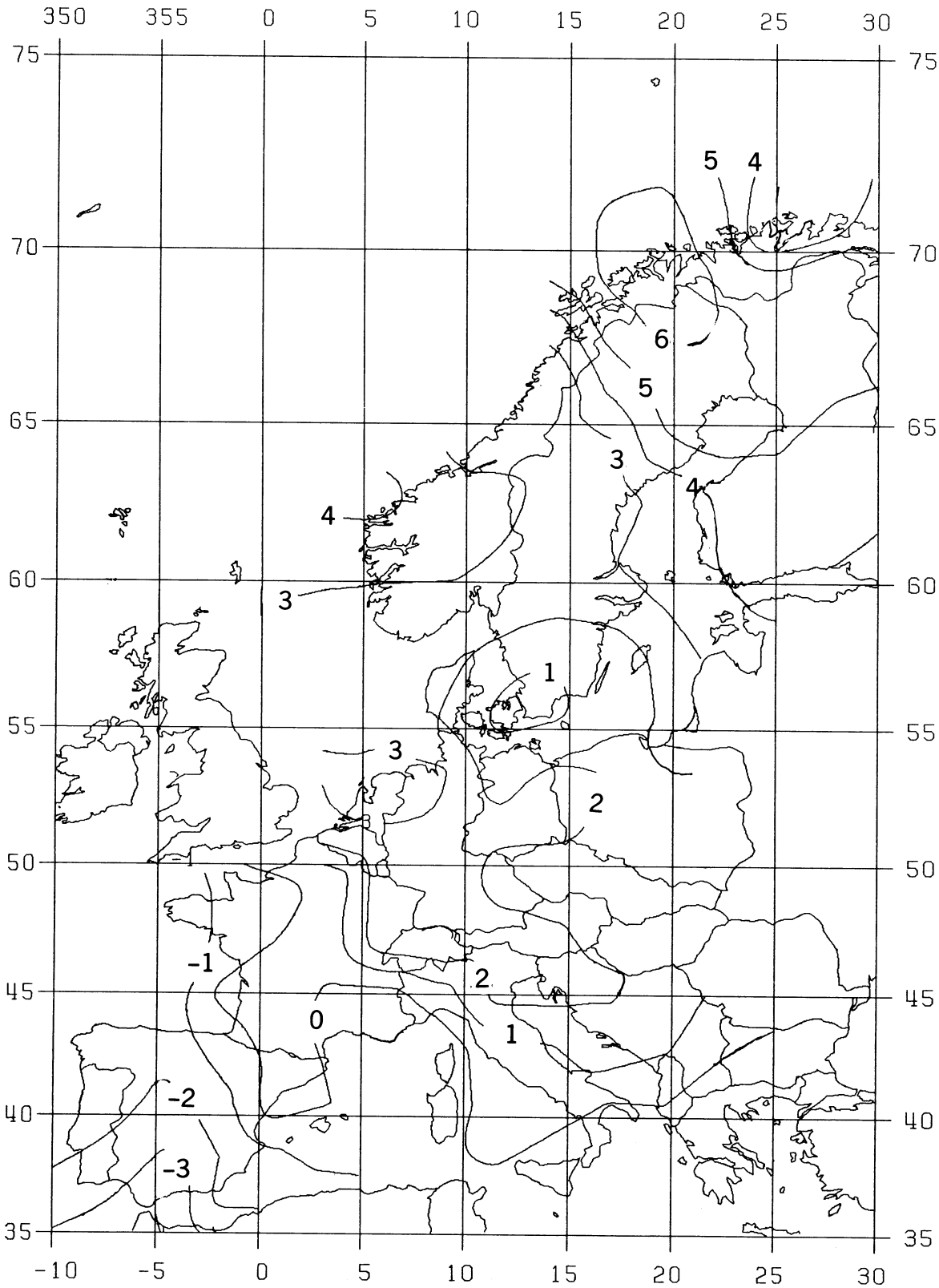

Figure 26.15. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (ED 50 Area, Western Europe) - (Units = 1 Meter)

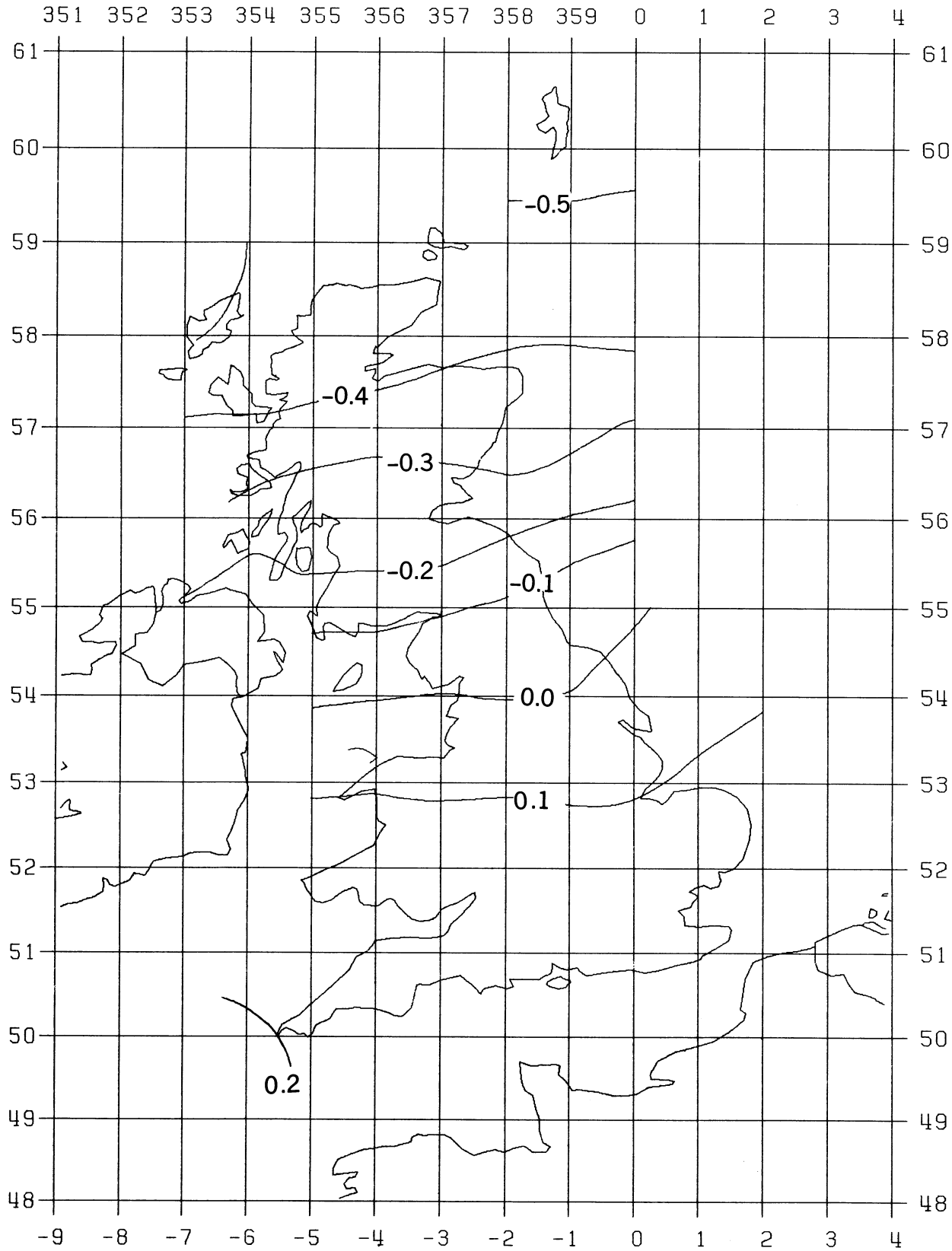

Figure 26.16. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (OSGB 36 Area) - (Units = 0.1 Arc Second)

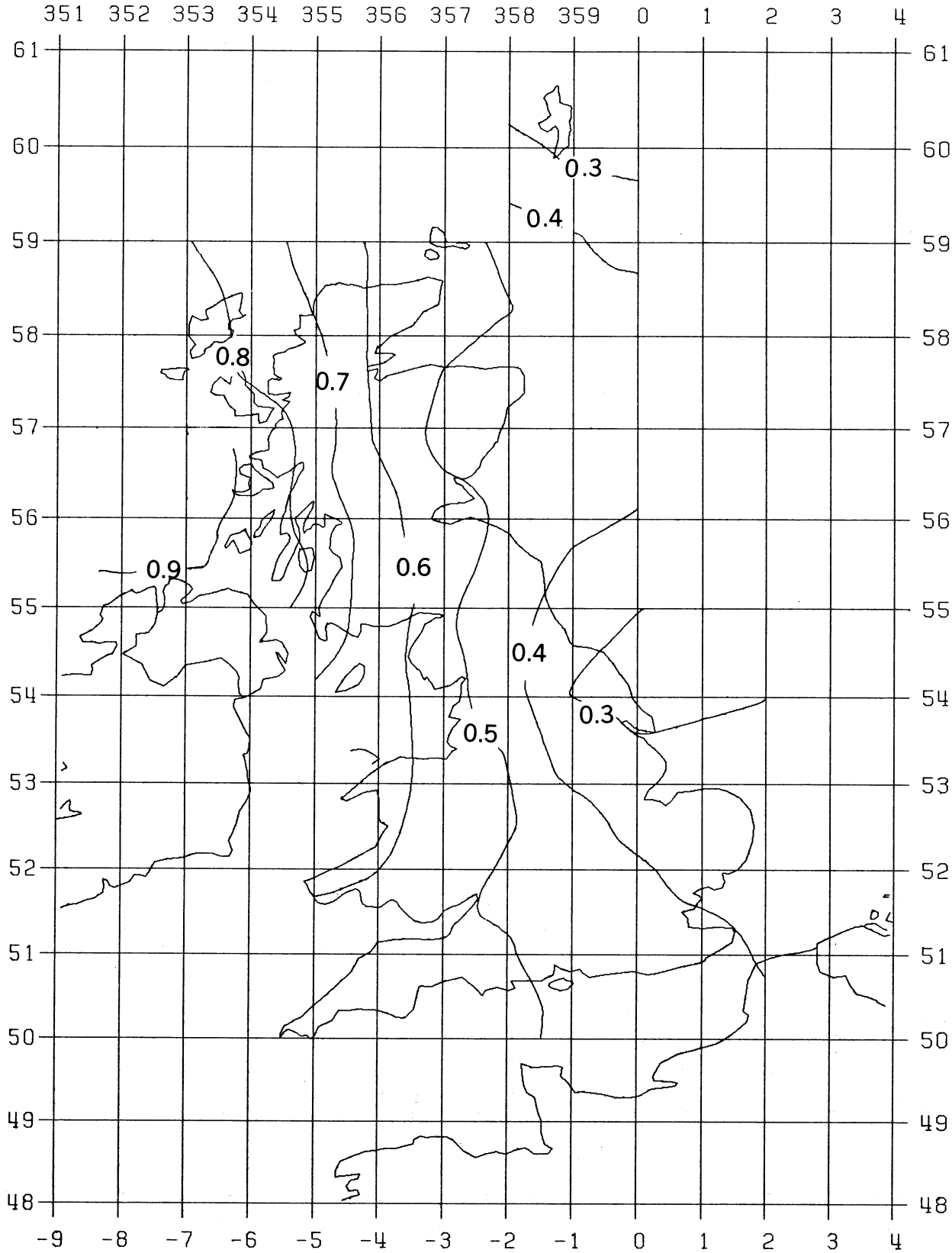

Figure 26.17. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (OSGB 36 Area) - (Units = 0.1 Arc Second)

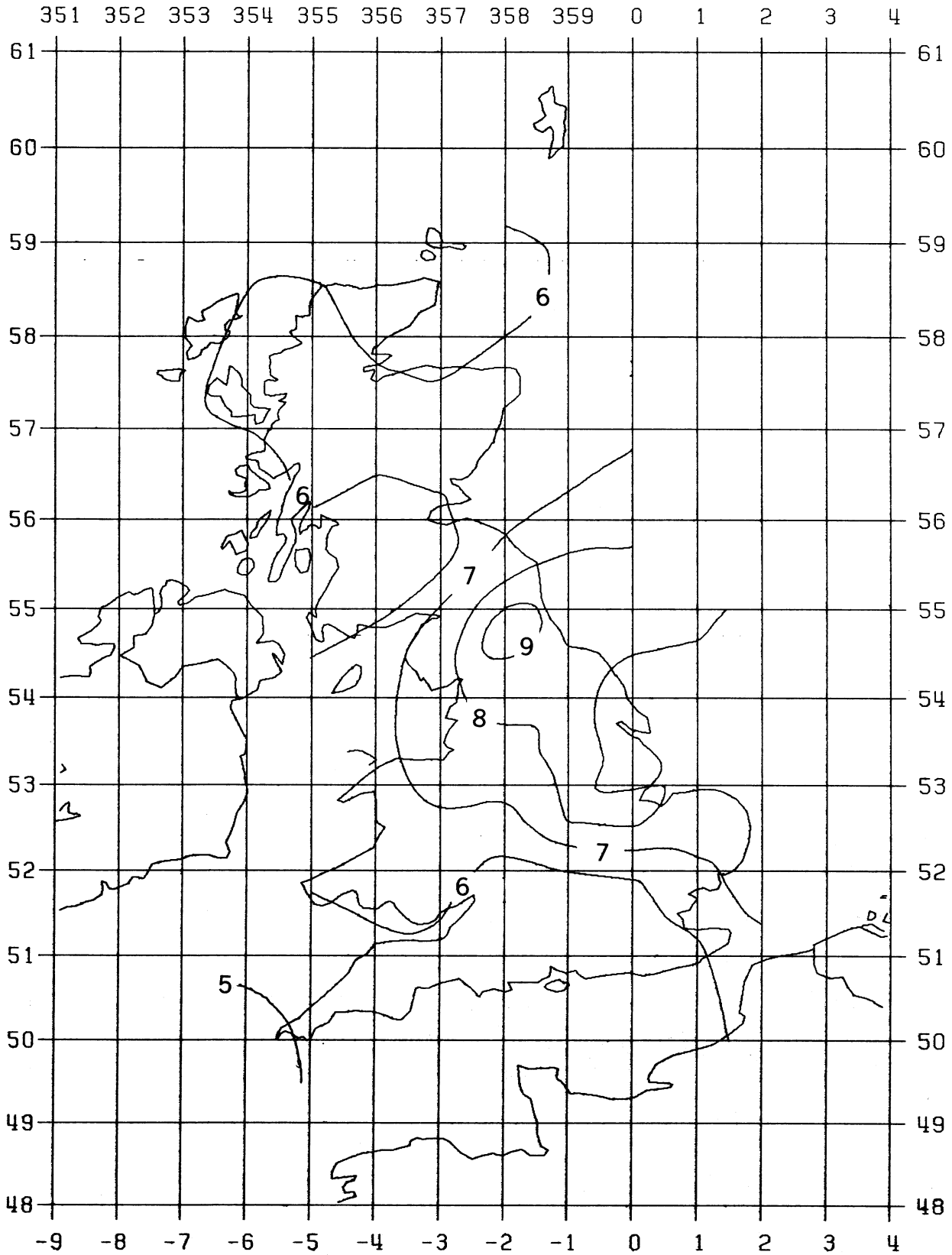

Figure 26.18. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (OSGB 36 Area) - (Units = 1 Meter)

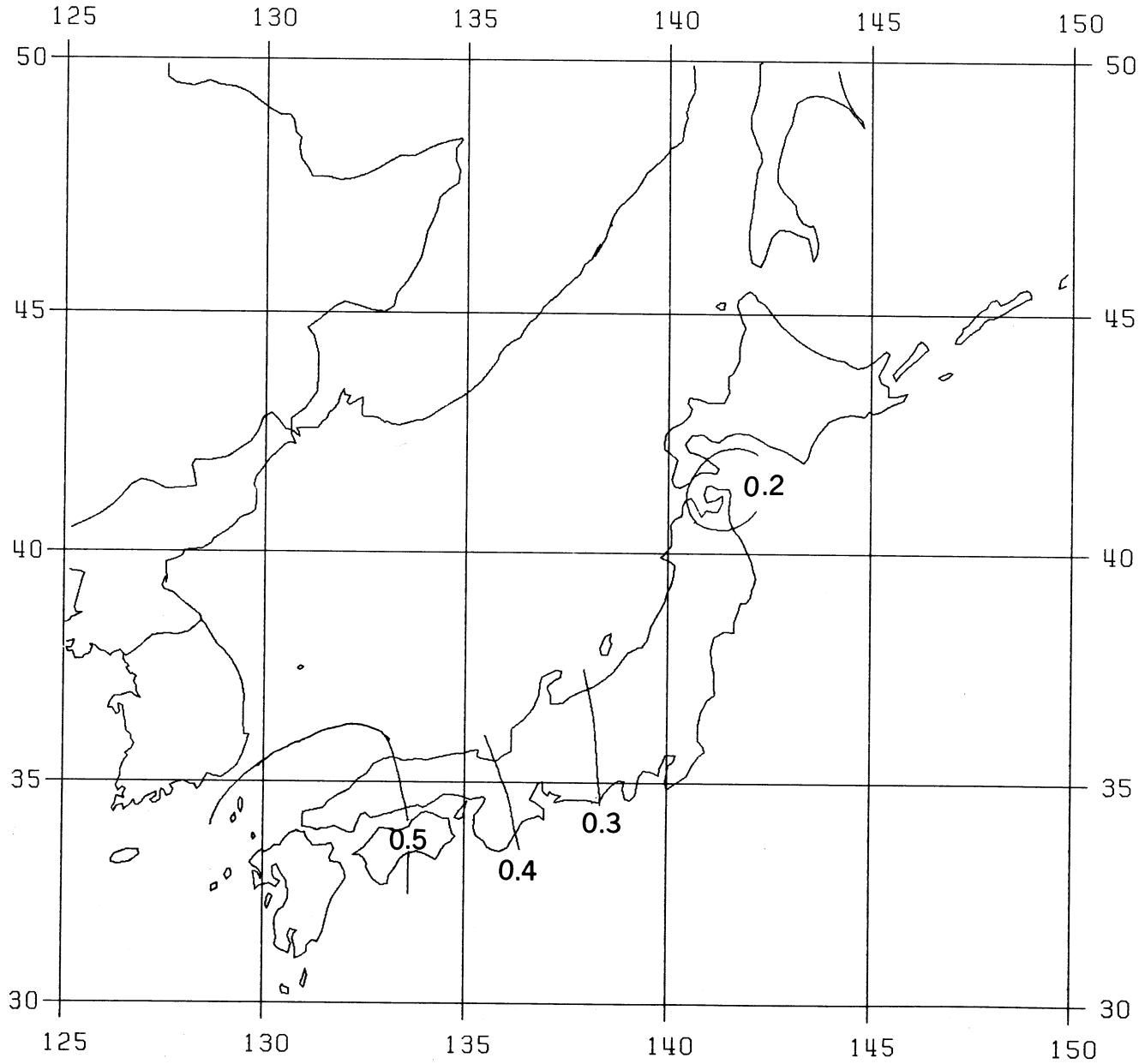

Figure 26.19. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (TD Area) - (Units = 0.1 Arc Second)

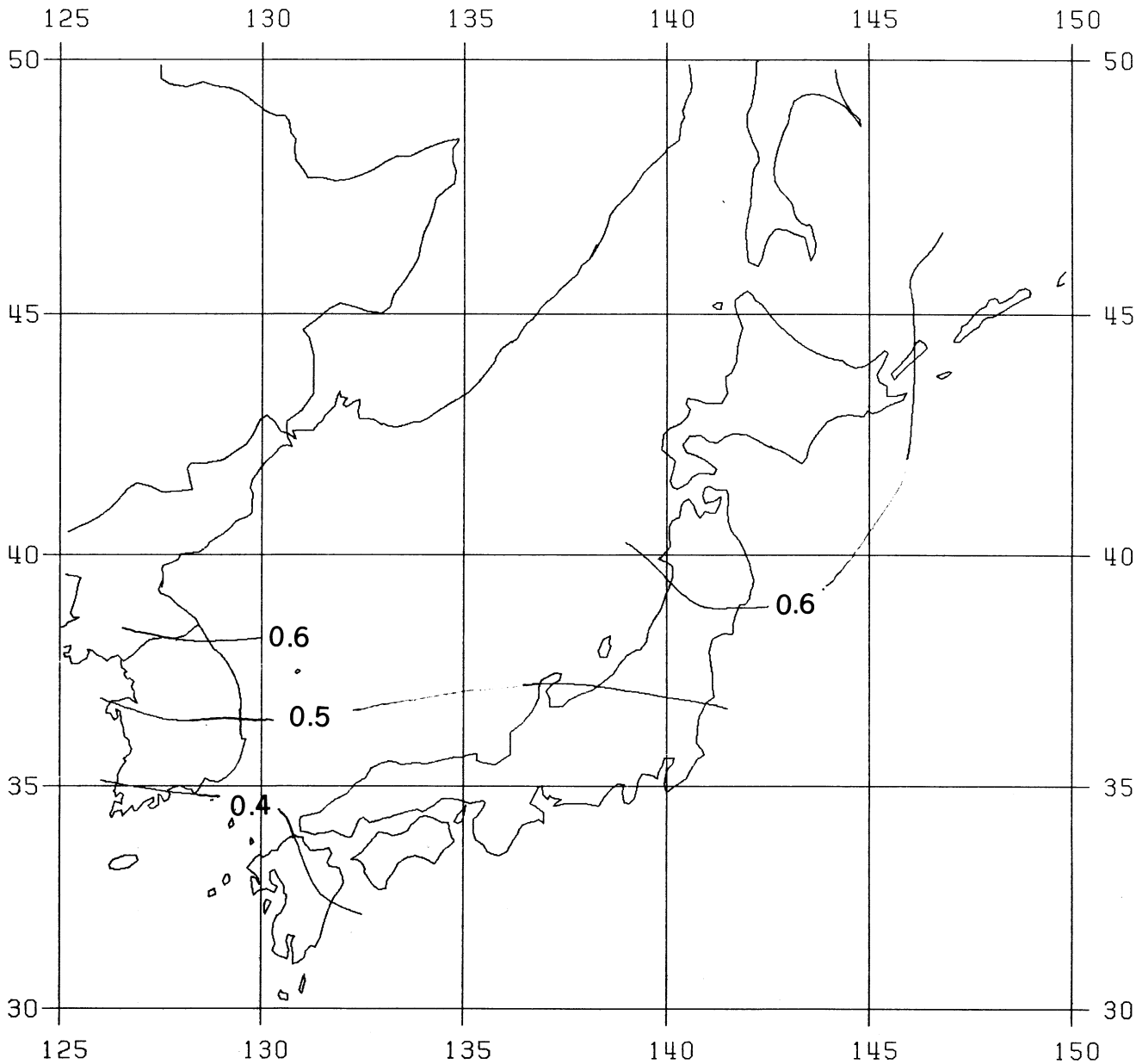

Figure 26.20. Maximum Longitude Differences in Converting WGS-72 Coordinates to WGS 84 (TD Area) - (Units = 0.1 Arc Second)

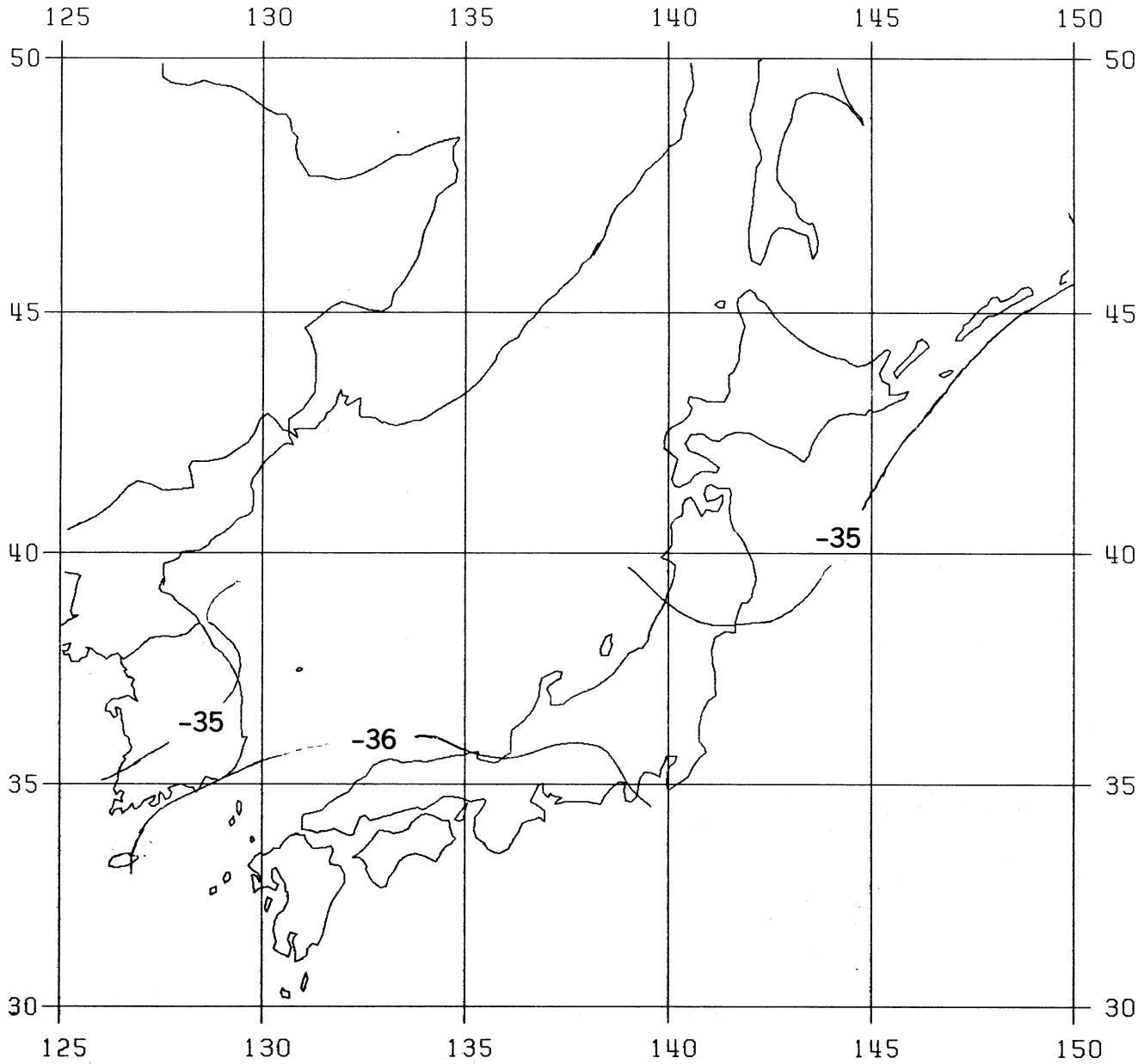

Figure 26.21. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (TD Area) - (Units = 1 Meter)

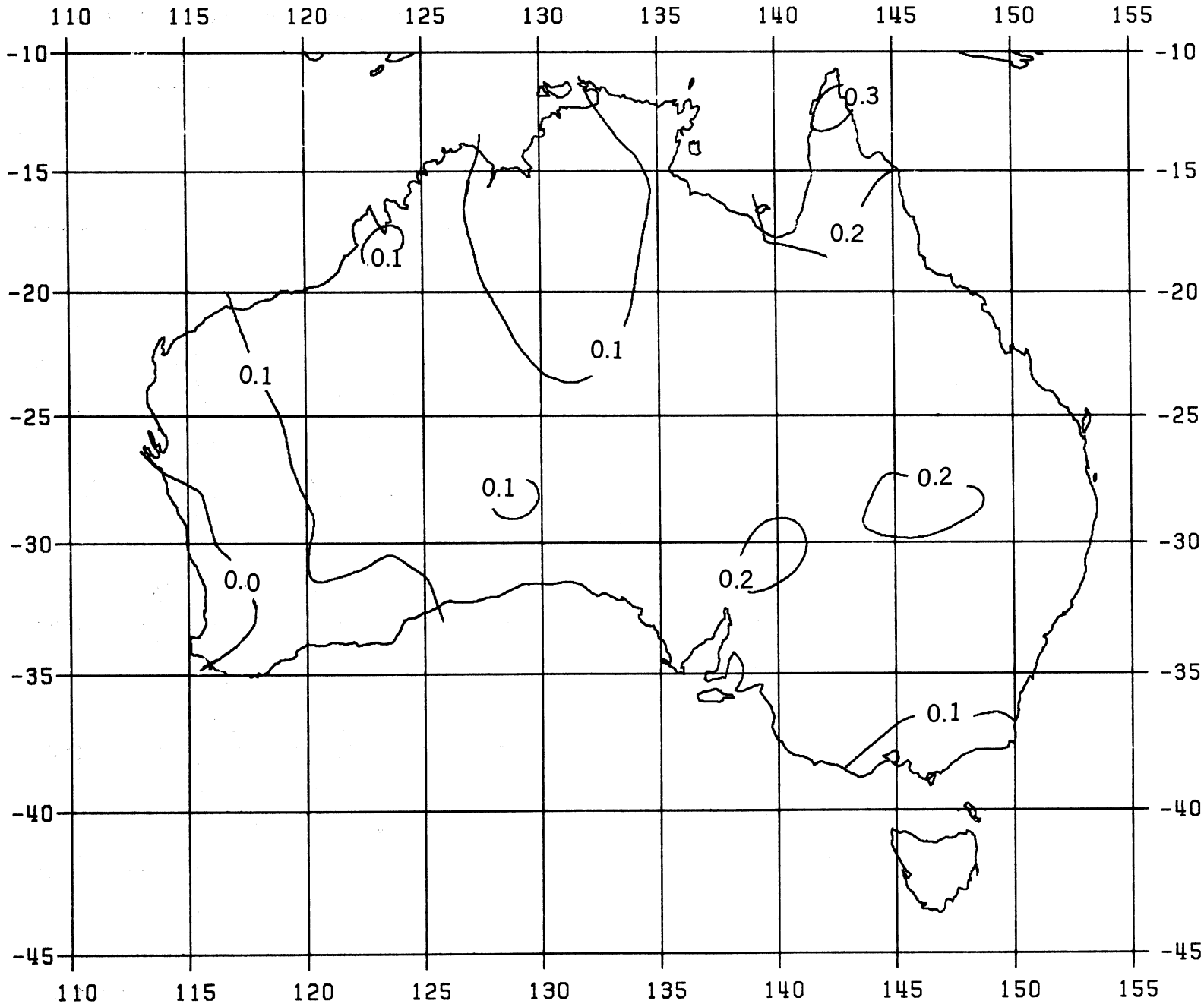

Figure 26.22. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (AGD 66 Area) - (Units = 0.1 Arc Second)

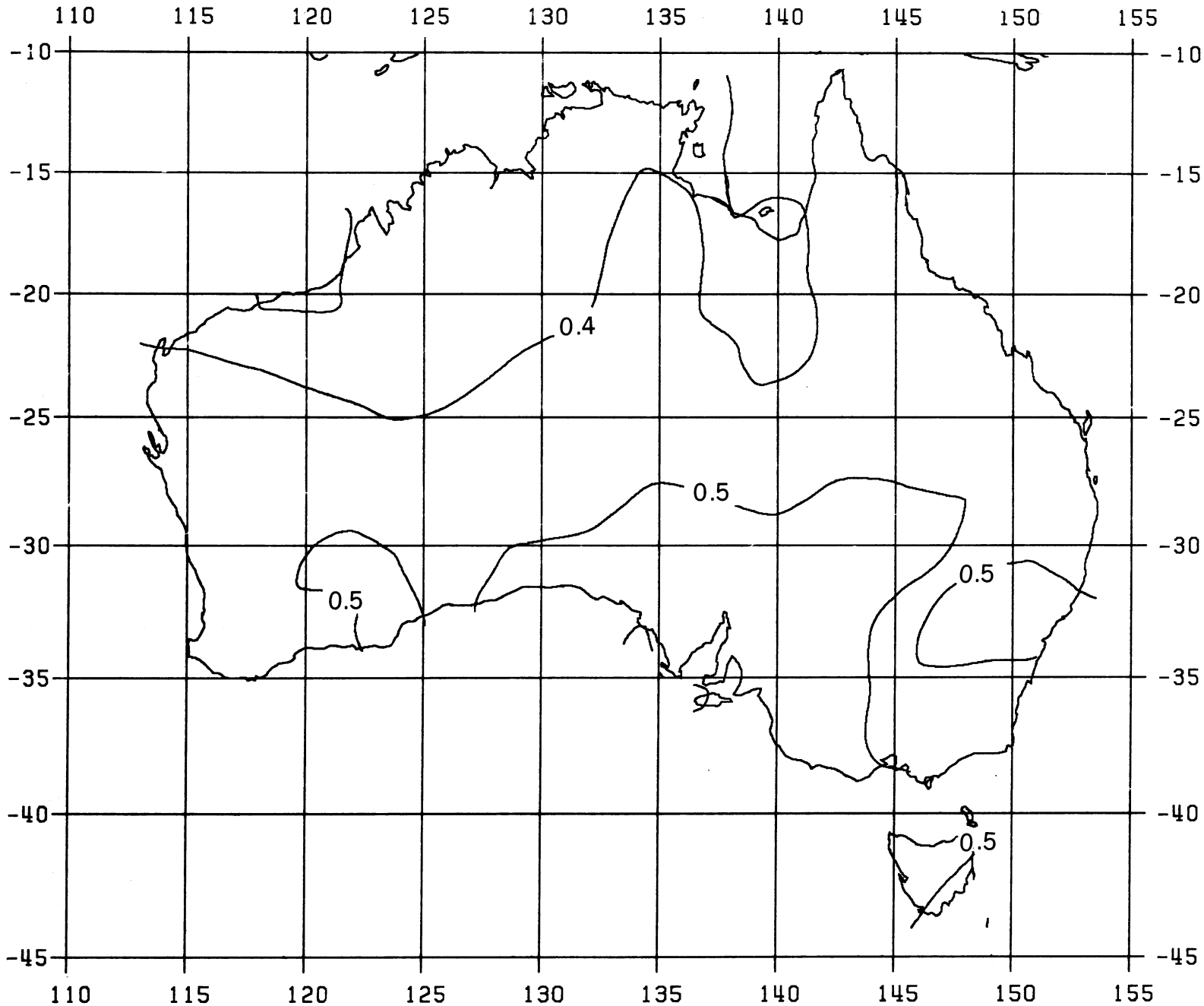

Figure 26.23. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (AGD 66 Area)-(Units = 0.1 Arc Second)

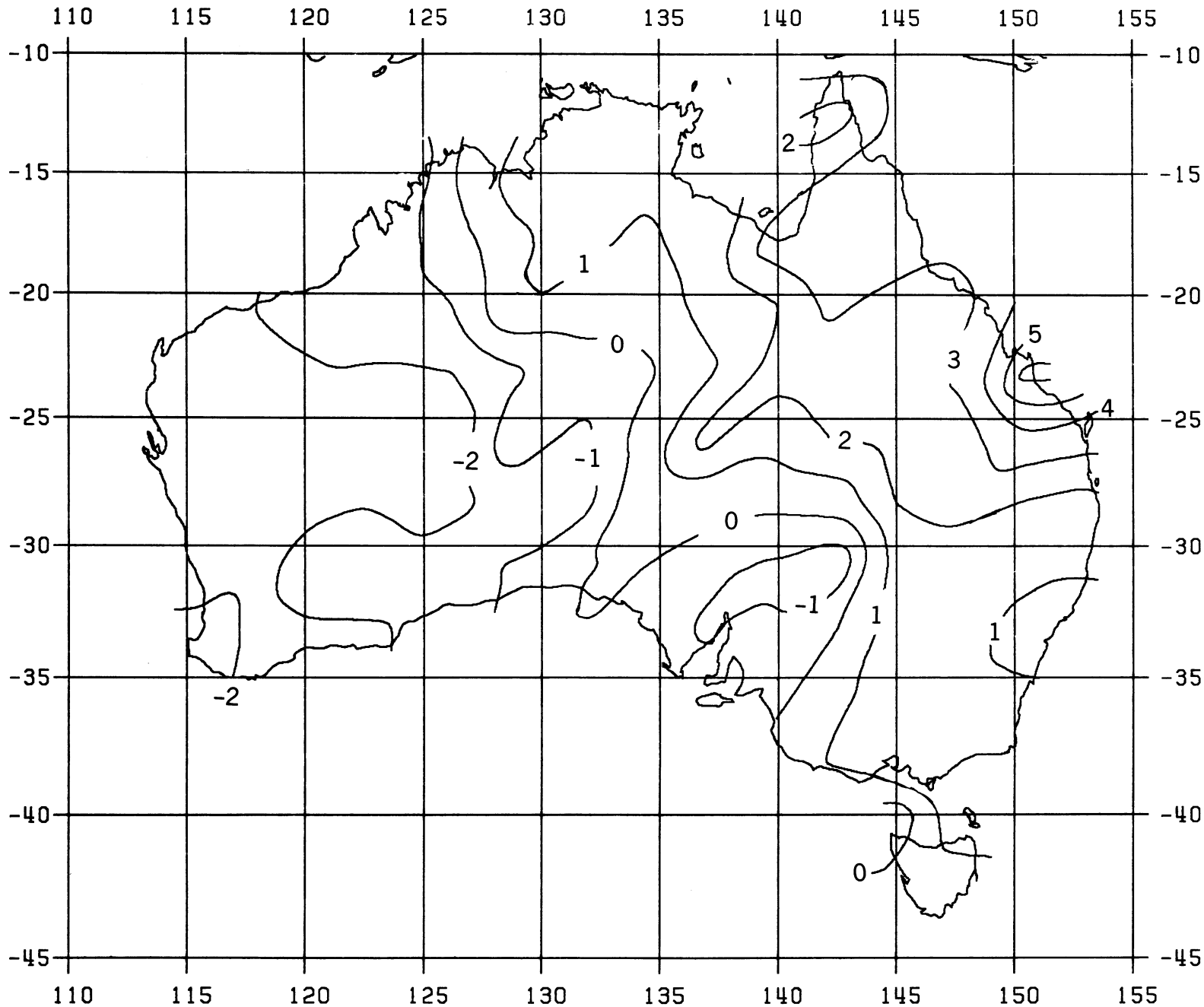

Figure 26.24. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (AGD 66 Area)-(Units = 1 Meter)

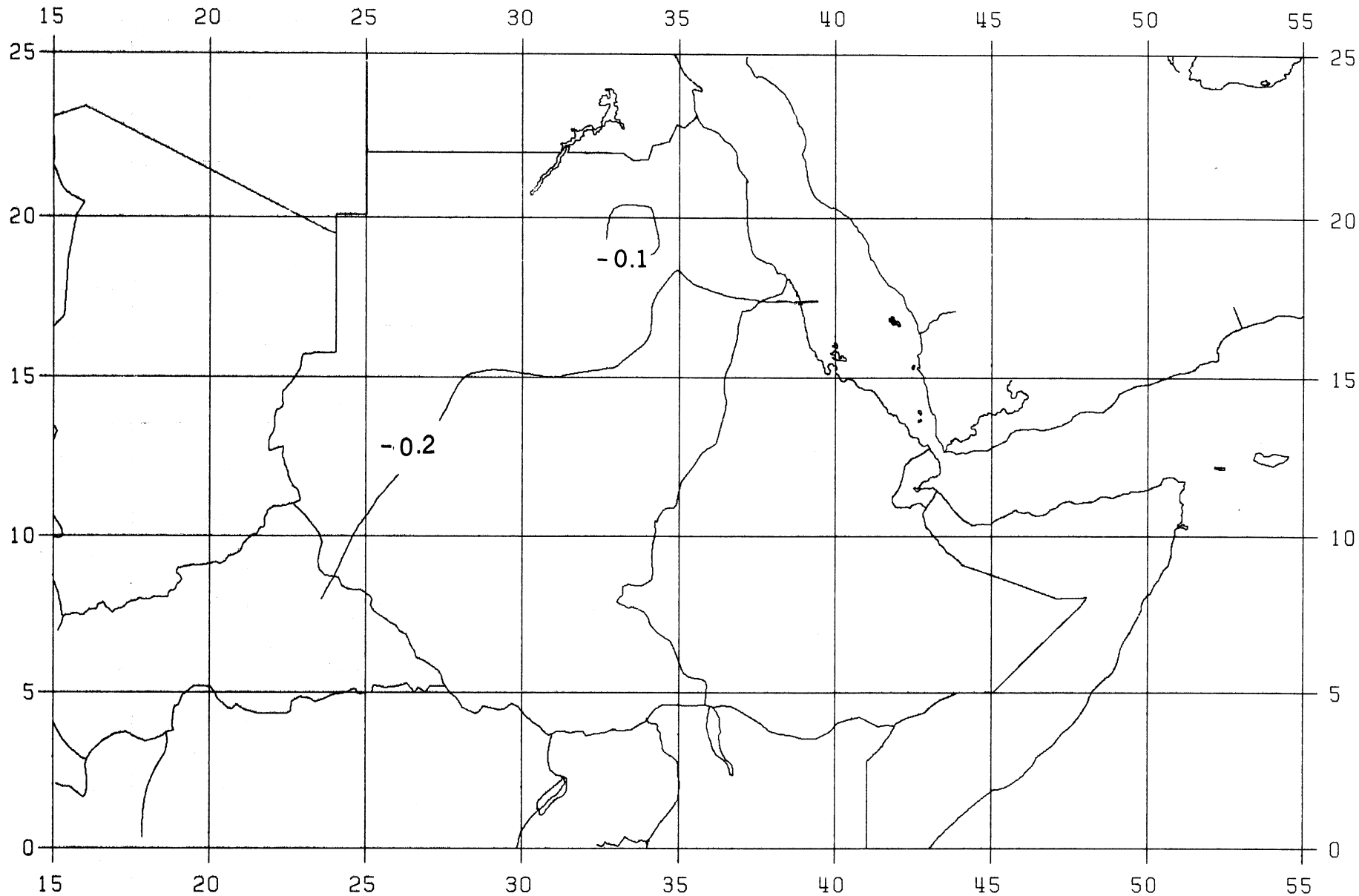

Figure 26.25. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (Adindan Datum Area)-(Units = 0.1 Arc Second)

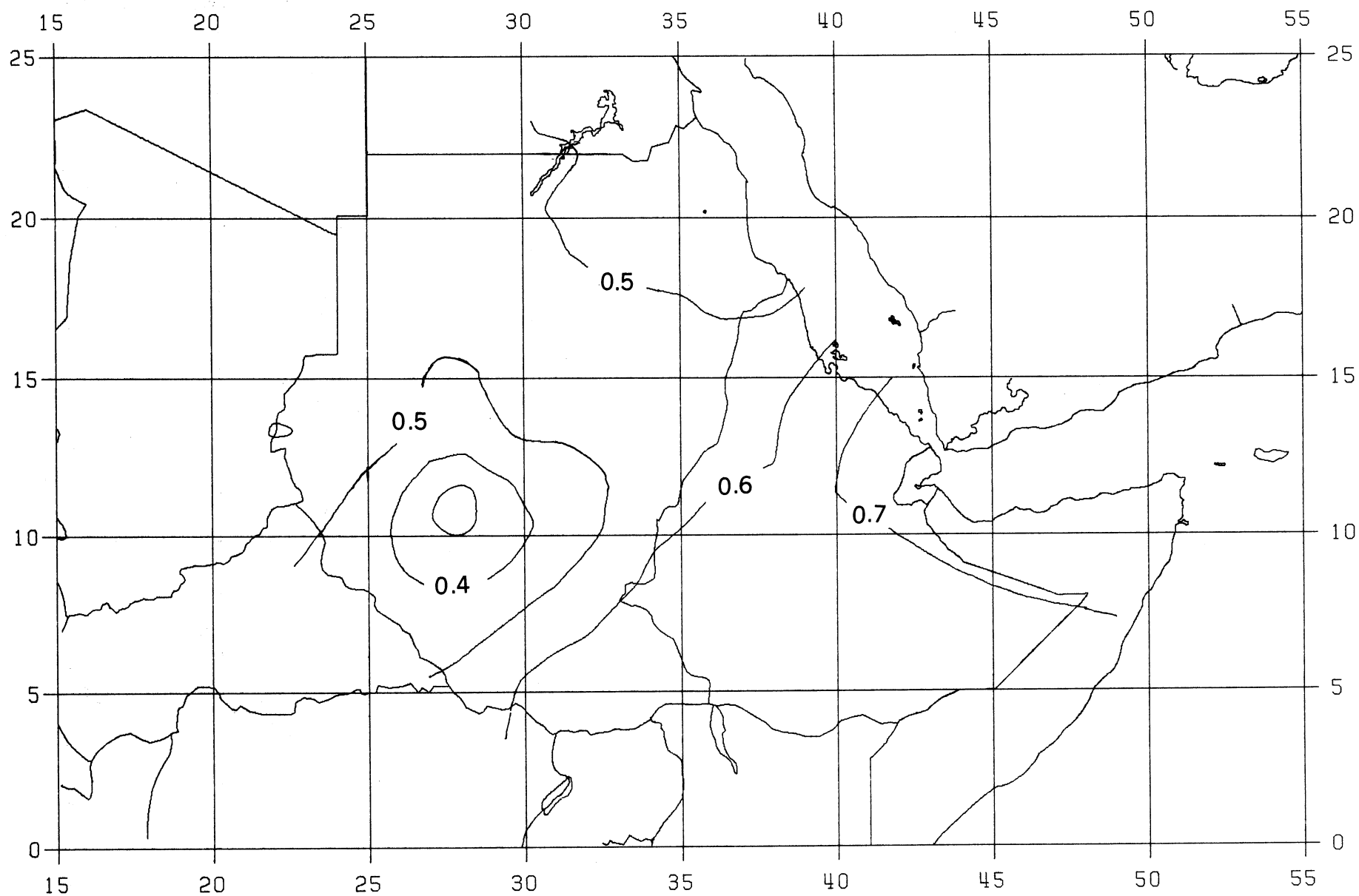

Figure 26.26. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (Adindan Datum Area)-(Units = 0.1 Arc Second)

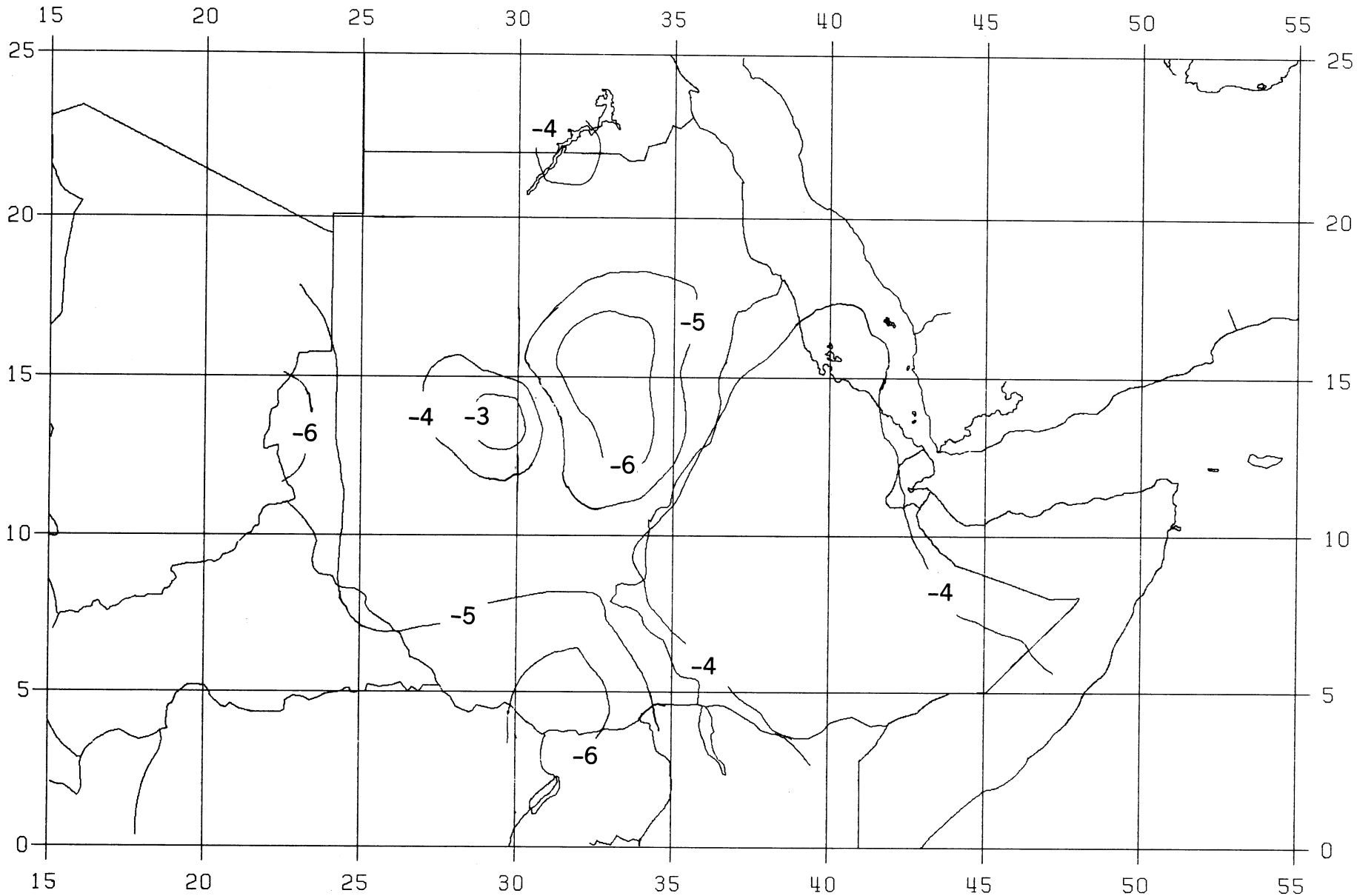

Figure 26.27. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (Adindan Datum Area)-(Units = 1 Meter)

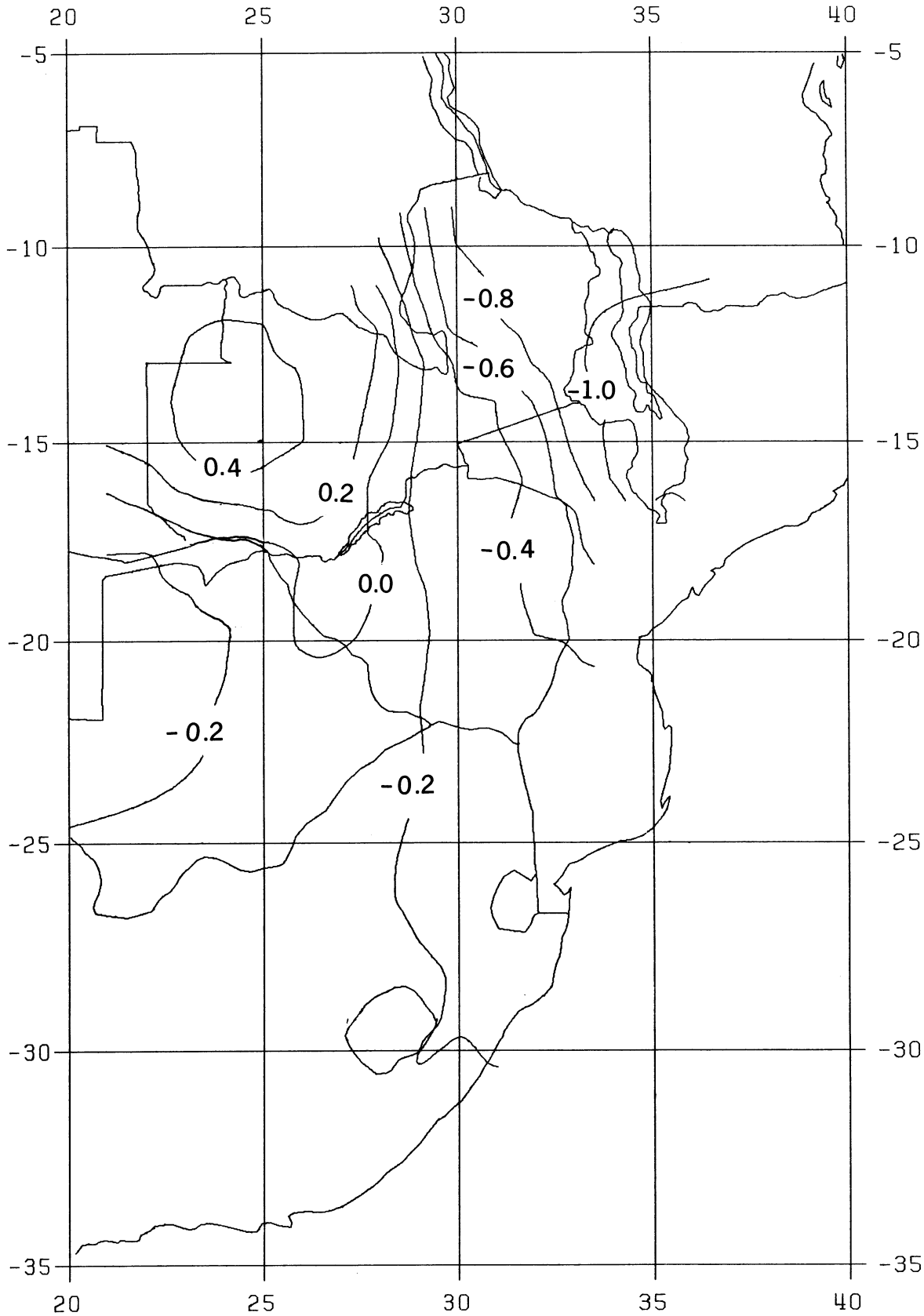

Figure 26.28. Maximum Latitude Differences in Converting WGS 72 Coordinates to WGS 84 (Arc Datum 1950 Area) - (Units = 0.2 Arc Second)

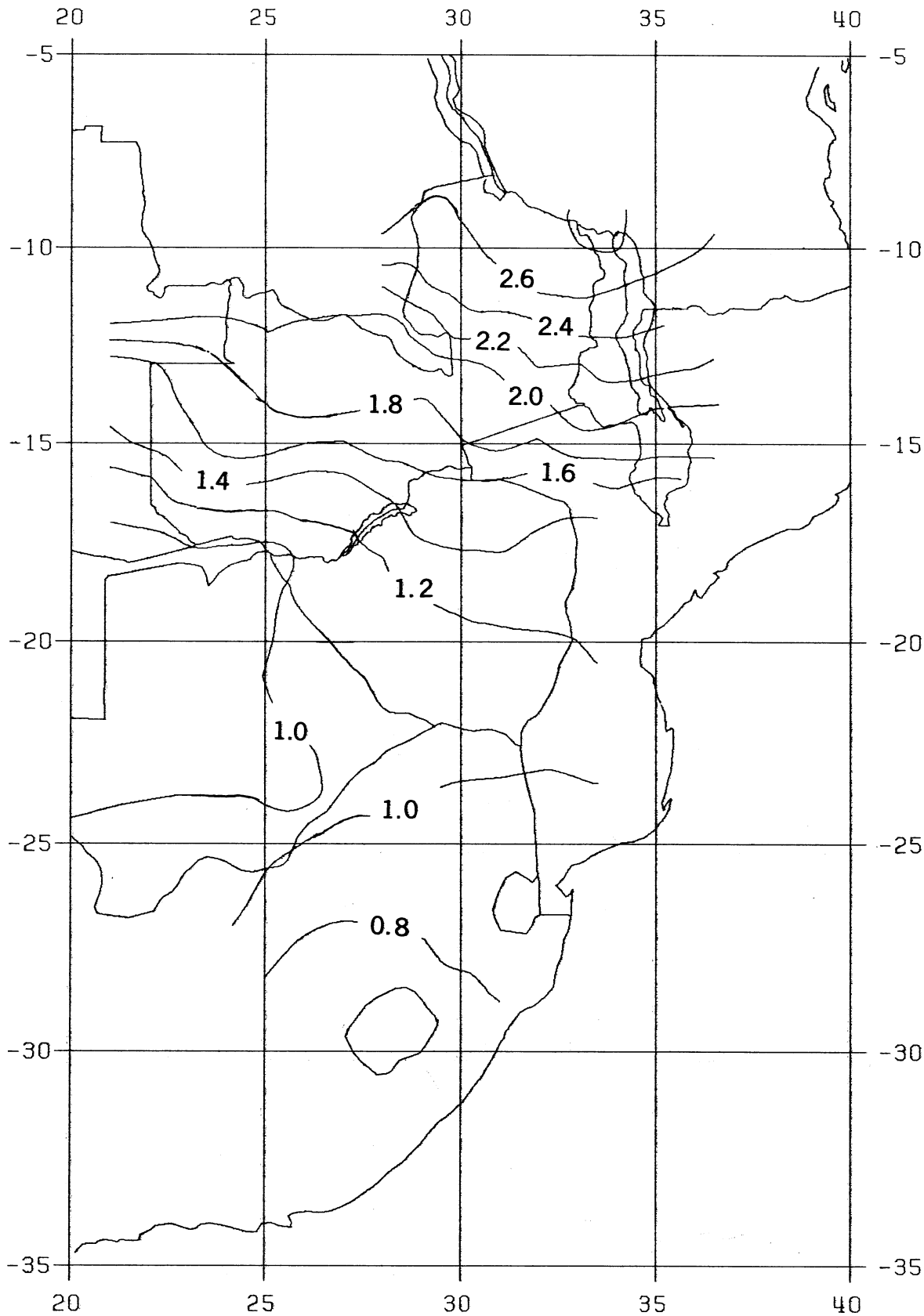

Figure 26.29. Maximum Longitude Differences in Converting WGS 72 Coordinates to WGS 84 (Arc Datum 1950 Area) - (Units = 0.2 Arc Second)

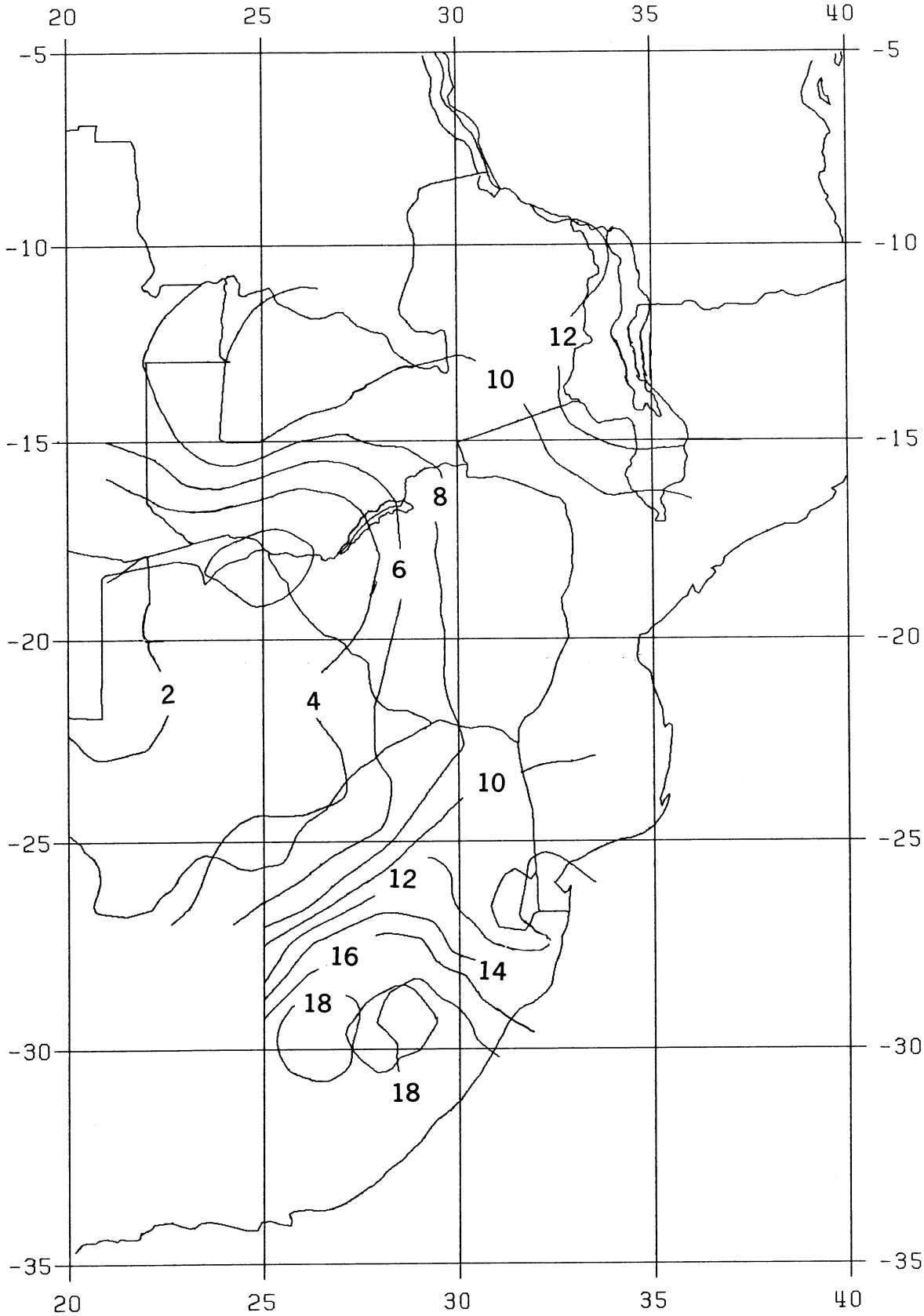

Figure 26.30. Maximum Geodetic Height Differences in Converting WGS 72 Coordinates to WGS 84 (Arc Datum 1950 Area) - (Units = 2 Meters)

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SECTION 27

ACCURACY OF WGS 84 COORDINATES

Table 27.1

Accuracy (1σ) of WGS 84 Coordinates
As a Function of Coordinate Determination Technique

WGS 84 Coordinates of Site Determined Using	Accuracies (1σ) Geodetic Latitude	Geodetic Longitude	Geodetic Height
Satellite Point Positioning Directly in WGS 84	±1 m	±1 m	±1-2 m
NSWC 9Z-2 to WGS 84 Transformation	2	2	2-3
Localized ΔX, ΔY, ΔZ Datum Shifts (Tabular or From ΔX, ΔY, ΔZ Datum Shift Contour Charts) and Standard Molodensky Datum Transformation Formulas	2*	2*	2-3*
Localized ΔX, ΔY, ΔZ Datum Shifts and Direct Coordinate Conversion (X, Y, Z to ϕ, λ, H)	2*	2*	2-3*
$\Delta\phi$, $\Delta\lambda$, ΔH Datum Shift Contour Charts	3**	3**	2-3**
Datum Shift Multiple Regression Equations ($\Delta\phi$, $\Delta\lambda$, ΔH)	3***	3***	4***
$\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$ Mean Datum Shifts and Standard Molodensky Datum Transformation Formulas	5***	4***	4***
$\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$ Mean Datum Shifts and Direct Coordinate Conversion (X, Y, Z to ϕ, λ, H)	5***	4***	4***

* Pertains only to the use of localized ΔX, ΔY, ΔZ datum shifts (tabular or from ΔX, ΔY, ΔZ Datum Shift Contour Charts). Applicable only in the vicinity of Doppler stations; the errors are larger elsewhere [and if mean datum shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) are used].

** Applicable only in the vicinity of Doppler stations. The errors are larger elsewhere.

*** These are general accuracy values pertaining to NAD 27 (CONUS), and will not necessarily be the same for other local geodetic systems. (See Tables 27.2 and 27.3 for these and other general accuracy values, and then Figures 27.1 - 27.42 for how the accuracy values vary throughout the datum areas.)

Table 27.1 (Cont'd)

Accuracy (1σ) of WGS 84 Coordinates
As a Function of Coordinate Determination Technique

WGS 84 Coordinates of Site Determined Using	Accuracies (1σ) Geodetic Latitude	Geodetic Longitude	Geodetic Height
WGS 72 to WGS 84 Transformation Formulas:			
- At Doppler Stations (WGS 72 Coordinates from Satellite Point Positioning)	±2 m	±2 m	±2-3 m
- At Non-Doppler Geodetic Network Stations:			
- Near Doppler Stations, WGS 72 Coordinates from Localized Datum Shifts	3	3	3-4
- WGS 72 Coordinates from Mean Datum Shifts	[Use Only as a Last Resort; Large Errors. See Sections 11 and 26 of this Report, and Sections 7.2.3 and 9.3 of Reference 2.]		

Table 27.2

Accuracy (1σ) of WGS 84 Coordinates at Doppler Sites
- WGS 84 Coordinates Determined Using Molodensky Datum Transformation Formulas and Local Geodetic System-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) -

Local Geodetic Systems	Number of Comparison Points	Linear Error Geodetic Latitude ($\sigma_{D_{\ell_\phi}}$)	Linear Error Geodetic Longitude ($\sigma_{D_{\ell_\lambda}}$)	Linear Error Geodetic Height ($\sigma_{D_{\ell_H}}$)	Circular (Horizontal) Error (σ_{D_c})	Spherical (Positional) Error (σ_{D_s})
Adindan	25	±4.2m	±4.5m	±4.1m	5.1m	5.1m
Arc 1950	41	13.7	26.3	5.3	29.1	29.0
Arc 1960	19	5.2	7.1	4.2	7.5	7.4
Australian Geodetic 1966	105	3.1	2.9	3.5	3.1	3.3
Australian Geodetic 1984	90	2.8	2.9	3.5	2.9	3.1
Bellevue (IGN)	3	2.8	2.7	3.8	2.7	3.1
Bermuda 1957	3	2.8	2.9	4.2	2.9	3.3
Bogota Observatory	7	5.2	4.8	5.1	5.8	6.0
Campo Inchauspe	20	3.5	3.5	4.5	3.7	4.2
Canton Astro 1966	4	2.6	2.5	4.3	2.5	3.1
Cape	5	5.9	4.4	3.6	6.0	5.7
Cape Canaveral	16	2.3	2.2	3.4	2.3	2.6
Carthage	5	7.3	7.5	3.8	8.8	8.3
Chatham 1971	4	2.4	2.4	3.7	2.4	2.8
Chua Astro	6	5.0	6.3	5.6	6.7	7.0
Corrego Alegre	17	4.0	4.2	3.5	4.5	4.8
Djakarta	5	2.2	2.7	4.0	2.5	2.9
European 1950						
Western Europe	85	3.2	5.7	3.6	5.5	5.4
* UK/Ireland	47	2.2	2.3	3.4	2.2	2.6
* UK (Only)	40	2.2	2.3	3.5	2.2	2.6
Cyprus	4	2.3	2.3	3.7	2.3	2.7
Egypt	14	5.2	6.2	5.1	7.0	7.2

* ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates.

Table 27.2 (Cont'd)

Accuracy (1σ) of WGS 84 Coordinates at Doppler Sites
- WGS 84 Coordinates Determined Using Molodensky Datum Transformation Formulas and Local Geodetic System-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) -

Local Geodetic Systems	Number of Comparison Points	Linear Error Geodetic Latitude ($\sigma_{D_{\ell_\phi}}$)	Longitude ($\sigma_{D_{\ell_\lambda}}$)	Height ($\sigma_{D_{\ell_H}}$)	Circular (Horizontal) Error (σ_{D_c})	Spherical (Positional) Error (σ_{D_s})
European 1950 (Cont'd)						
Iran	27	±5.5m	±8.0m	±9.6m	8.4m	10.8m
Geodetic Datum 1949	14	4.7	2.8	3.7	4.2	4.1
Guam 1963	5	2.6	2.4	3.9	2.5	3.0
Hjorsey 1955	6	2.5	2.9	5.5	2.7	3.9
Indian	14	6.3	6.8	3.4	7.9	7.5
Ireland 1965	7	2.3	2.4	3.3	2.4	2.6
Kandawala	3	2.9	3.3	3.8	3.1	3.3
Kertau 1948	6	3.1	3.0	3.6	3.2	3.3
Liberia 1964	4	4.4	9.4	3.8	8.9	8.3
Luzon	7	10.7	7.5	5.8	11.4	11.3
Merchich	9	2.4	2.7	5.3	2.6	3.8
Minna	6	4.2	4.7	3.7	4.9	4.8
NAD 27						
Alaska	47	4.6	6.4	4.3	6.9	6.7
Canada	112	8.3	10.8	4.2	12.7	11.8
CONUS	405	5.2	3.6	3.7	5.1	5.0
Mexico, Central America	44	4.9	9.1	5.3	9.0	8.9
Caribbean	26	8.1	5.4	4.8	8.6	8.5
NAD 83	203	2.1	2.3	3.5	2.2	2.6
Old Egyptian	14	5.4	4.5	5.2	5.7	6.1
Old Hawaiian	13	5.2	5.2	4.4	6.0	6.0
Oman	7	6.8	2.6	3.7	5.8	5.5
Ordnance Survey of Great Britain 1936	38	8.8	3.9	3.4	8.2	7.7

Table 27.2 (Cont'd)

Accuracy (1σ) of WGS 84 Coordinates at Doppler Sites
- WGS 84 Coordinates Determined Using Molodensky Datum Transformation Formulas and Local Geodetic System-to-WGS 84 Mean Datum Shifts ($\overline{\Delta X}$, $\overline{\Delta Y}$, $\overline{\Delta Z}$) -

Local Geodetic Systems	Number of Comparison Points	Linear Error Geodetic Latitude ($\sigma_{D_{\ell_\phi}}$)	Longitude ($\sigma_{D_{\ell_\lambda}}$)	Height ($\sigma_{D_{\ell_H}}$)	Circular (Horizontal) Error (σ_{D_c})	Spherical (Positional) Error (σ_{D_s})
Provisional South American 1956	65	±23.6	±12.9	±9.6	28.6	27.0
Puerto Rico	11	3.0	3.0	3.7	3.1	3.3
Qatar National	3	2.5	2.7	4.0	2.6	3.0
South American 1969	84	6.3	10.8	5.1	11.9	11.1
Southwest Base	5	2.4	3.1	3.4	2.8	3.0
Timbalai 1948	8	4.5	4.3	3.4	4.9	4.6
Tokyo	11	5.5	5.3	3.8	6.3	6.1
Wake-Eniwetok 1960	7	2.3	2.8	3.6	2.6	2.9
Zanderij	5	5.8	5.0	3.5	6.1	5.7

NOTE: The accuracies listed in this table are general accuracy values determined using data developed at Doppler sites. See Figures 27.1 - 27.21 before deciding to use accuracy values from this table.

Table 27.3

Accuracy (1σ) of WGS 84 Coordinates at Doppler Sites
- WGS 84 Coordinates Determined Using Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations -

Local Geodetic Systems	Number of Comparison Points	Linear Error Geodetic Latitude ($\sigma_{D_{\ell_\phi}}$)	Longitude ($\sigma_{D_{\ell_\lambda}}$)	Height ($\sigma_{D_{\ell_H}}$)	Circular (Horizontal) Error (σ_{D_c})	Spherical (Positional) Error (σ_{D_s})
Adindan	25	±5.4m	±3.6m	±3.8m	5.6m	5.6m
Arc 1950	41	5.3	20.4	4.7	20.5	20.5
Arc 1960	19	3.2	2.8	3.9	3.2	3.5
Australian Geodetic 1966	105	2.4	2.4	3.4	2.4	2.8
Australian Geodetic 1984	90	2.3	2.3	3.5	2.3	2.7
Bellevue (IGN)	3	2.4	2.5	3.7	2.5	2.8
Bermuda 1957	3	2.5	2.5	3.8	2.5	2.9
Bogota Observatory	7	3.0	3.3	3.4	3.3	3.3
Campo Inchauspe	20	2.6	2.6	3.8	2.6	3.1
Canton Astro 1966	4	2.3	2.3	3.5	2.3	2.7
Cape	5	2.5	2.3	3.4	2.4	2.7
Cape Canaveral	16	2.2	2.3	3.3	2.3	2.6
Carthage	5	2.6	2.7	3.5	2.7	2.9
Chatham 1971	4	2.3	2.4	3.5	2.4	2.7
Chua Astro	6	3.0	2.3	3.5	2.7	3.0
Corrego Alegre	17	3.3	3.3	3.5	3.6	3.8
Djakarta	5	2.5	2.6	3.5	2.5	2.8
European 1950						
Western Europe	85	3.0	2.8	3.5	3.2	3.4
* UK/Ireland	47	2.1	2.3	3.3	2.2	2.5
* UK (Only)	40	2.1	2.3	3.4	2.2	2.6
Cyprus	4	2.3	2.3	3.5	2.3	2.7
Egypt	14	2.6	2.9	3.5	2.8	3.0

* ED 50 coordinates developed from OSGB Scientific Network 1980 (SN 80) coordinates.

Table 27.3 (Cont'd)

Accuracy (1σ) of WGS 84 Coordinates at Doppler Sites
- WGS 84 Coordinates Determined Using Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations -

Local Geodetic Systems	Number of Comparison Points	Linear Error Geodetic Latitude ($\sigma_{D_{\ell_\phi}}$)	Longitude ($\sigma_{D_{\ell_\lambda}}$)	Height ($\sigma_{D_{\ell_H}}$)	Circular (Horizontal) Error (σ_{D_c})	Spherical (Positional) Error (σ_{D_s})
European 1950 (Cont'd)						
Iran	27	±4.8m	±4.5m	±5.6m	5.7m	6.6m
Geodetic Datum 1949	14	2.3	2.2	3.6	2.3	2.7
Guam 1963	5	2.5	2.3	3.8	2.4	2.8
Hjorsey 1955	6	2.7	2.5	3.8	2.6	3.0
Indian	14	4.9	2.9	4.1	4.6	4.7
Ireland 1965	7	2.3	2.4	3.3	2.4	2.7
Kandawala	3	2.5	2.6	3.7	2.5	2.9
Kertau 1948	6	2.6	2.6	3.6	2.6	2.9
Liberia 1964	4	2.3	3.0	3.5	2.6	2.9
Luzon	7	2.8	3.2	4.0	3.0	3.4
Merchich	9	2.8	2.2	4.0	2.6	3.0
Minna	6	2.9	2.6	3.5	2.8	3.0
NAD 27						
Alaska	47	3.2	3.2	4.0	3.4	3.7
Canada	112	3.1	3.4	3.5	3.5	3.6
CONUS	405	2.6	2.7	3.5	2.8	3.1
Mexico, Central America	44	3.5	4.0	4.3	4.1	4.5
Caribbean	26	2.7	4.4	4.9	4.1	4.8
Old Egyptian	14	2.5	3.7	4.7	3.4	4.3
Old Hawaiian	13	2.7	2.2	3.6	2.5	2.9
Oman	7	2.4	2.7	3.3	2.5	2.8
Ordnance Survey of Great Britain 1936	38	2.1	2.3	3.2	2.2	2.5

Table 27.3 (Cont'd)

Accuracy (1σ) of WGS 84 Coordinates at Doppler Sites
- WGS 84 Coordinates Determined Using Local Geodetic System-to-WGS 84 Datum Transformation Multiple Regression Equations -

Local Geodetic Systems	Number of Comparison Points	Linear Error Geodetic Latitude ($\sigma_{D_{\ell_\phi}}$)	Longitude ($\sigma_{D_{\ell_\lambda}}$)	Height ($\sigma_{D_{\ell_H}}$)	Circular (Horizontal) Error (σ_{D_c})	Spherical (Positional) Error (σ_{D_s})
Provisional South American 1956	65	±22.2	±4.1	±8.5	25.1m	23.6m
Puerto Rico	11	2.4	2.5	3.4	2.5	2.8
Qatar National	3	2.4	2.5	3.7	2.5	2.8
South American 1969	84	3.5	3.5	4.7	3.9	4.5
Southwest Base	5	2.4	2.4	3.4	2.4	2.7
Timbalai 1948	8	2.3	2.5	3.3	2.4	2.7
Tokyo	13 **	6.1	5.0	4.2	6.8	6.7
Wake-Eniwetok 1960	7	2.2	2.2	3.3	2.2	2.6
Zanderij	5	2.7	2.9	3.6	2.8	3.0

** Number includes two Doppler Stations on Okinawa. Related entry in Table 27.2 does not include these two stations.

NOTE: The accuracies listed in this table are general accuracy values determined using data developed at Doppler sites. See Figures 27.22 - 27.42 before deciding to use accuracy values from this table.

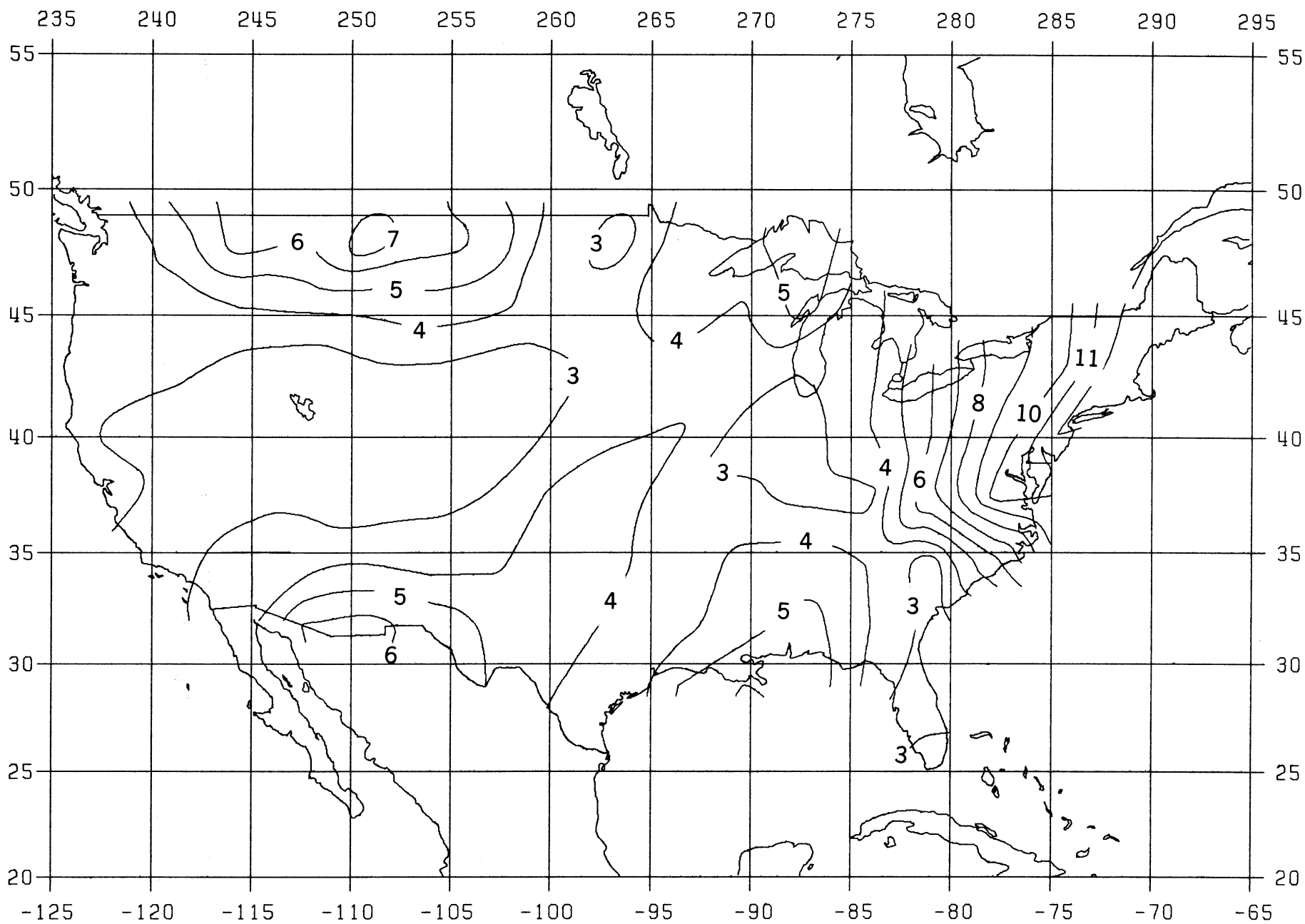

Figure 27.1. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (NAD 27 Area, CONUS), Latitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

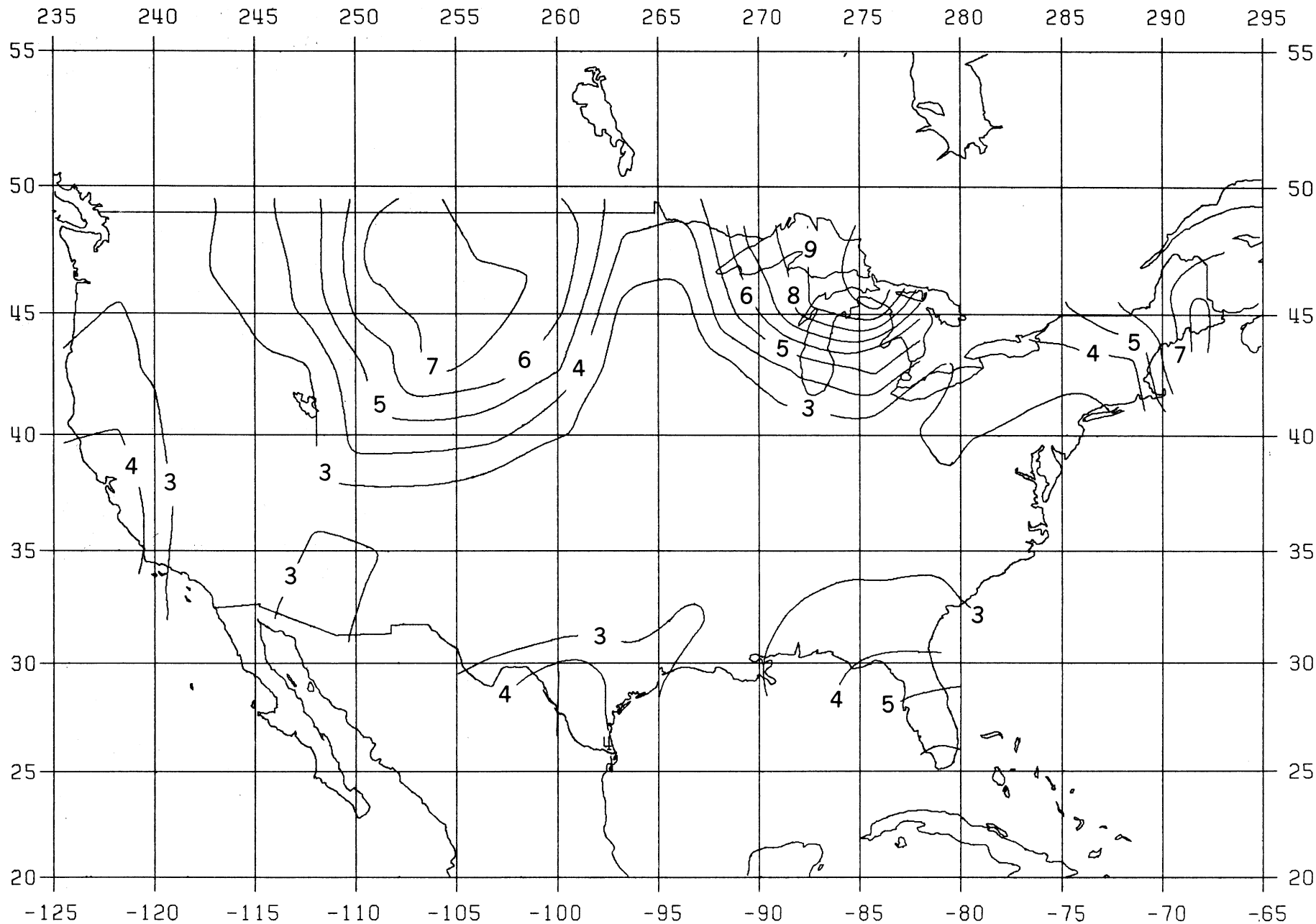

Figure 27.2. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (NAD 27 Area, CONUS), Longitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

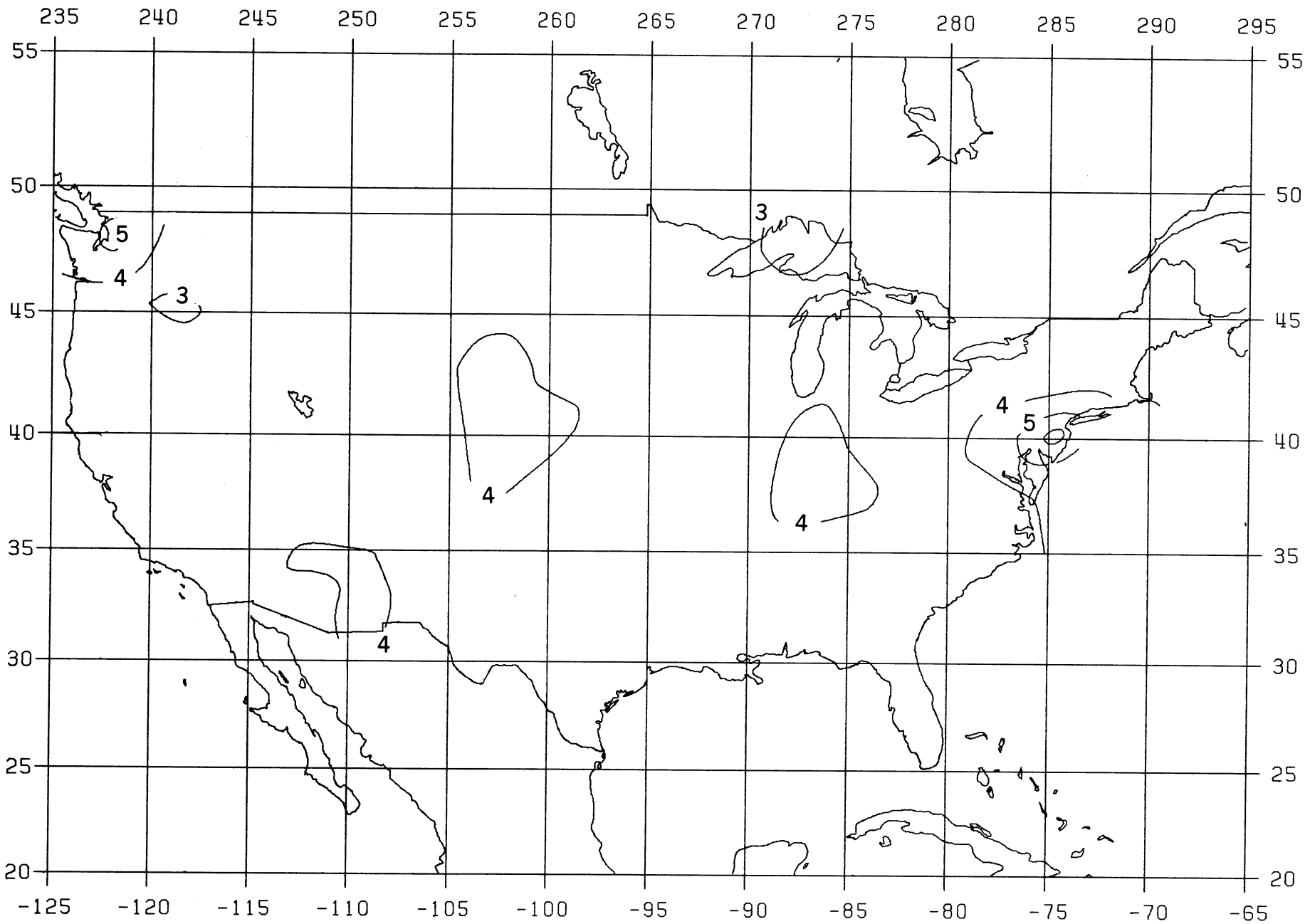

Figure 27.3. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (NAD 27 Area, CONUS), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

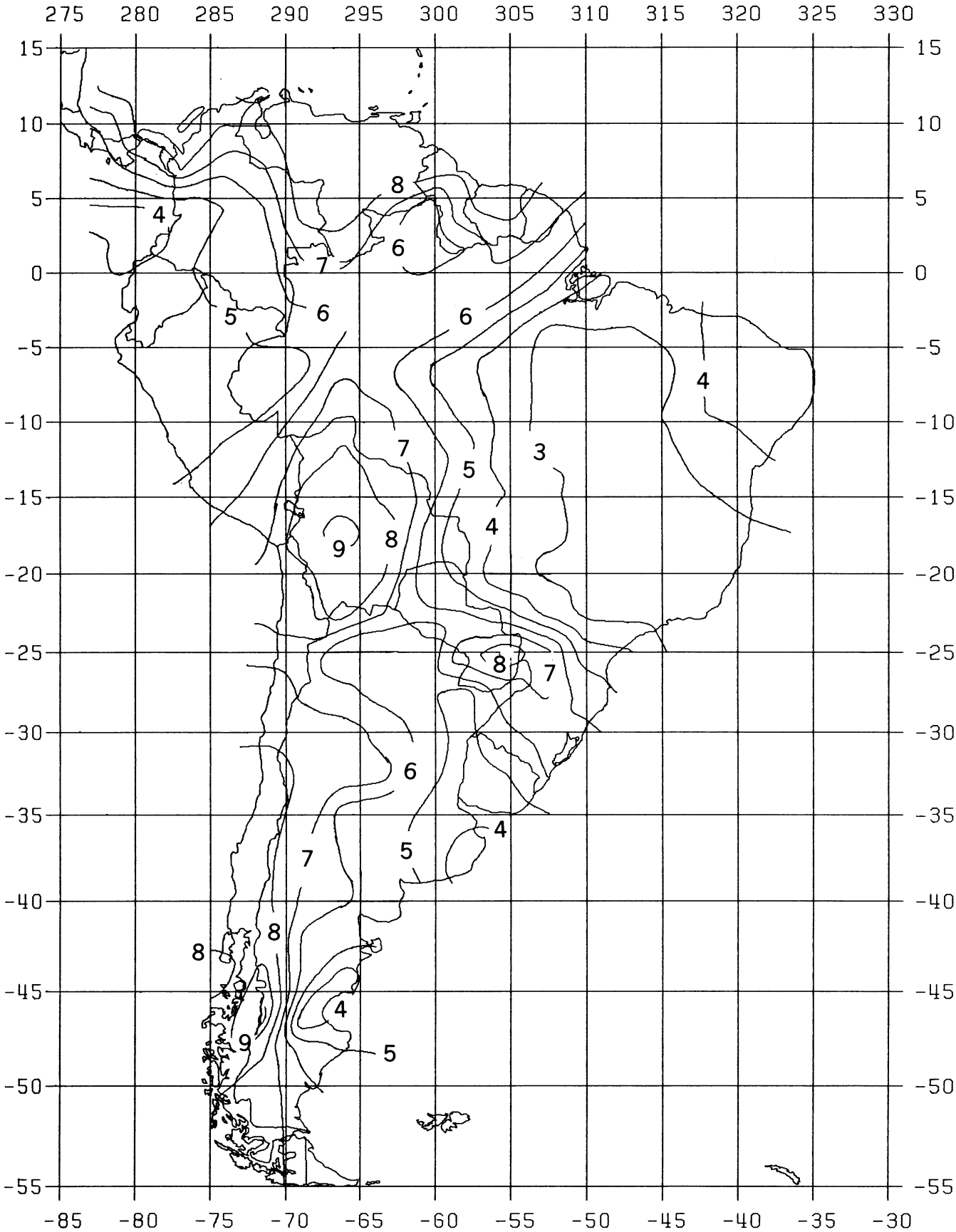

Figure 27.4. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (SAD 69 Area), Latitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

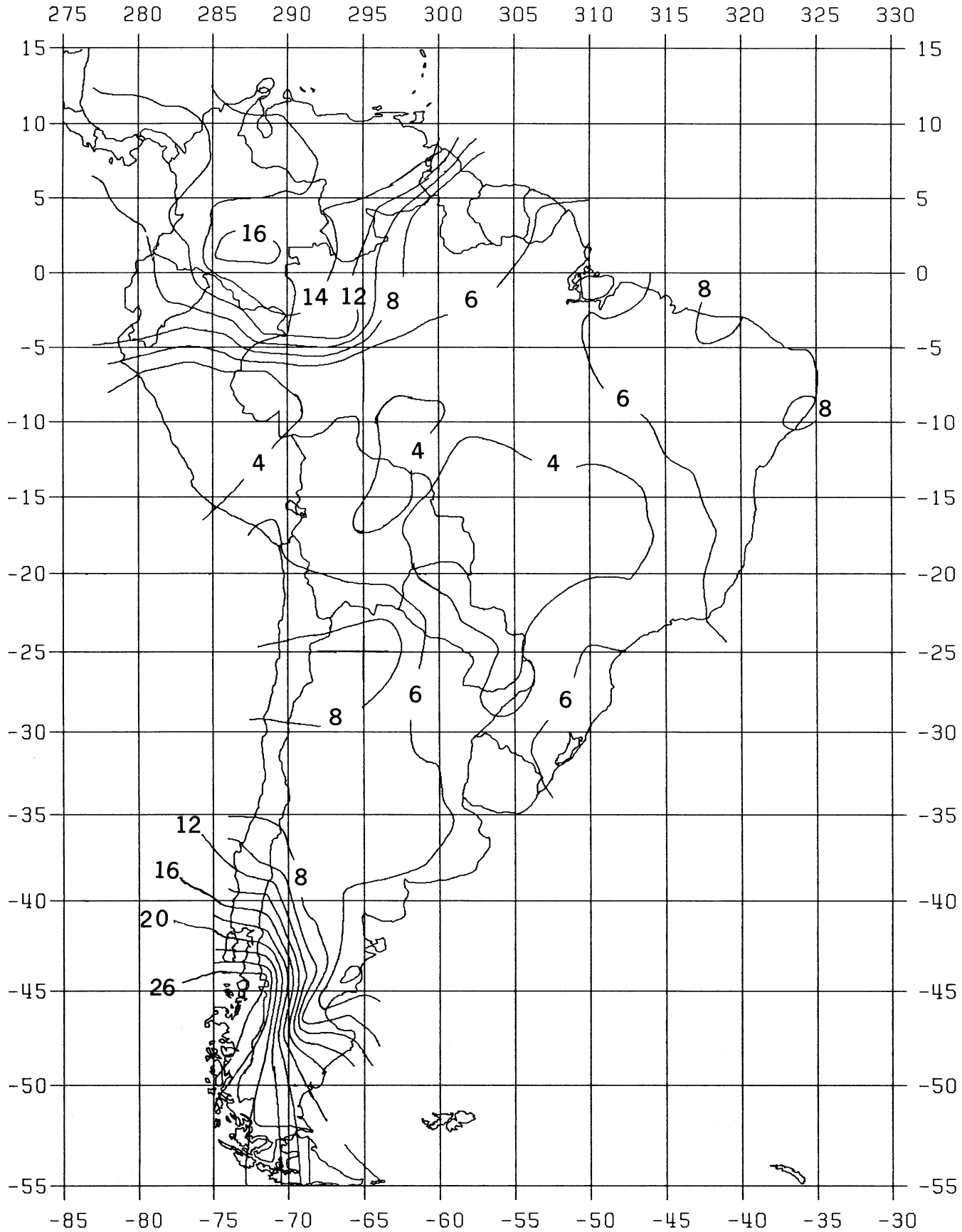

Figure 27.5. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (SAD 69 Area), Longitude Determined Using Mean Datum Shifts (Contour Interval = 2 Meters)

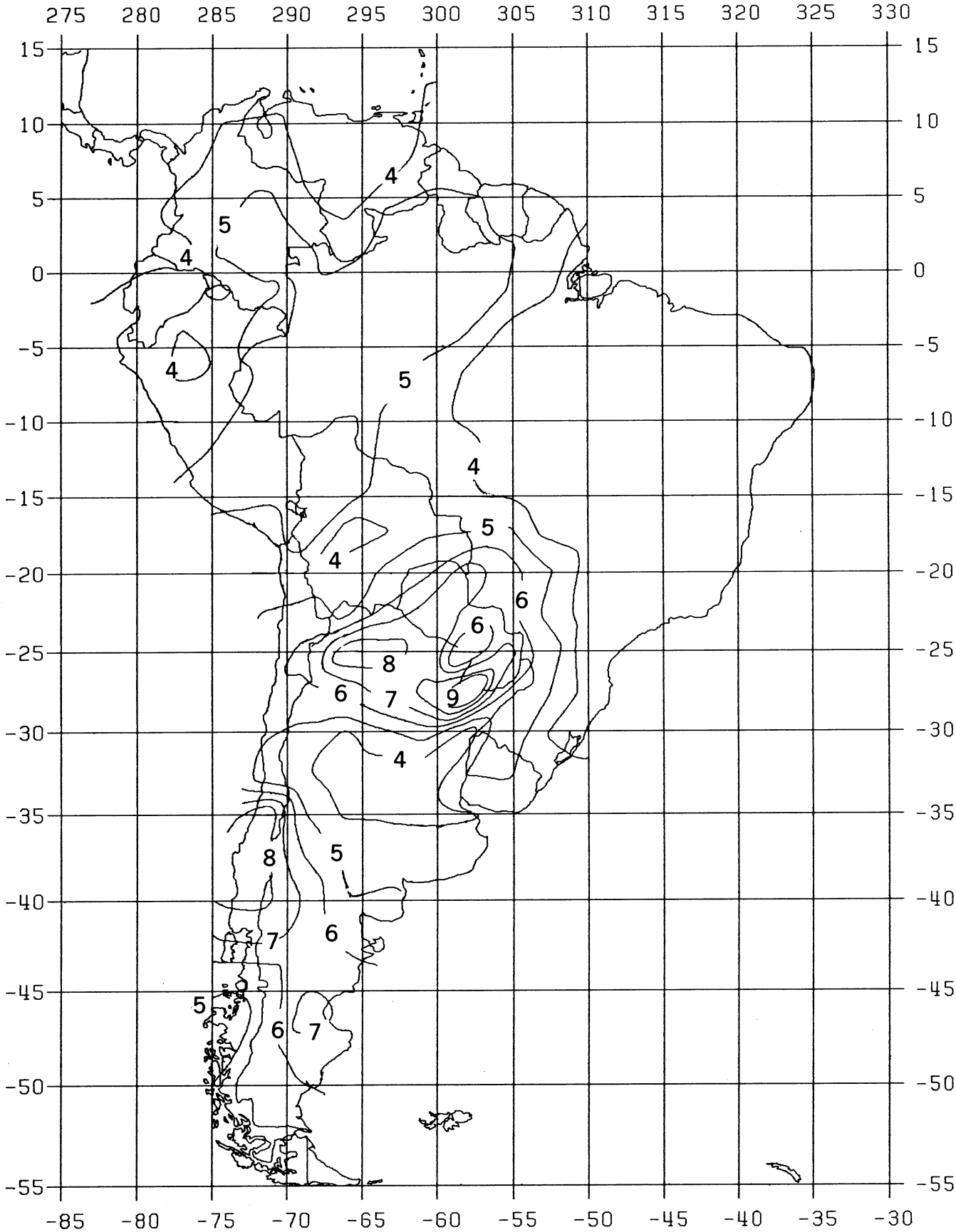

Figure 27.6. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (SAD 69 Area), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

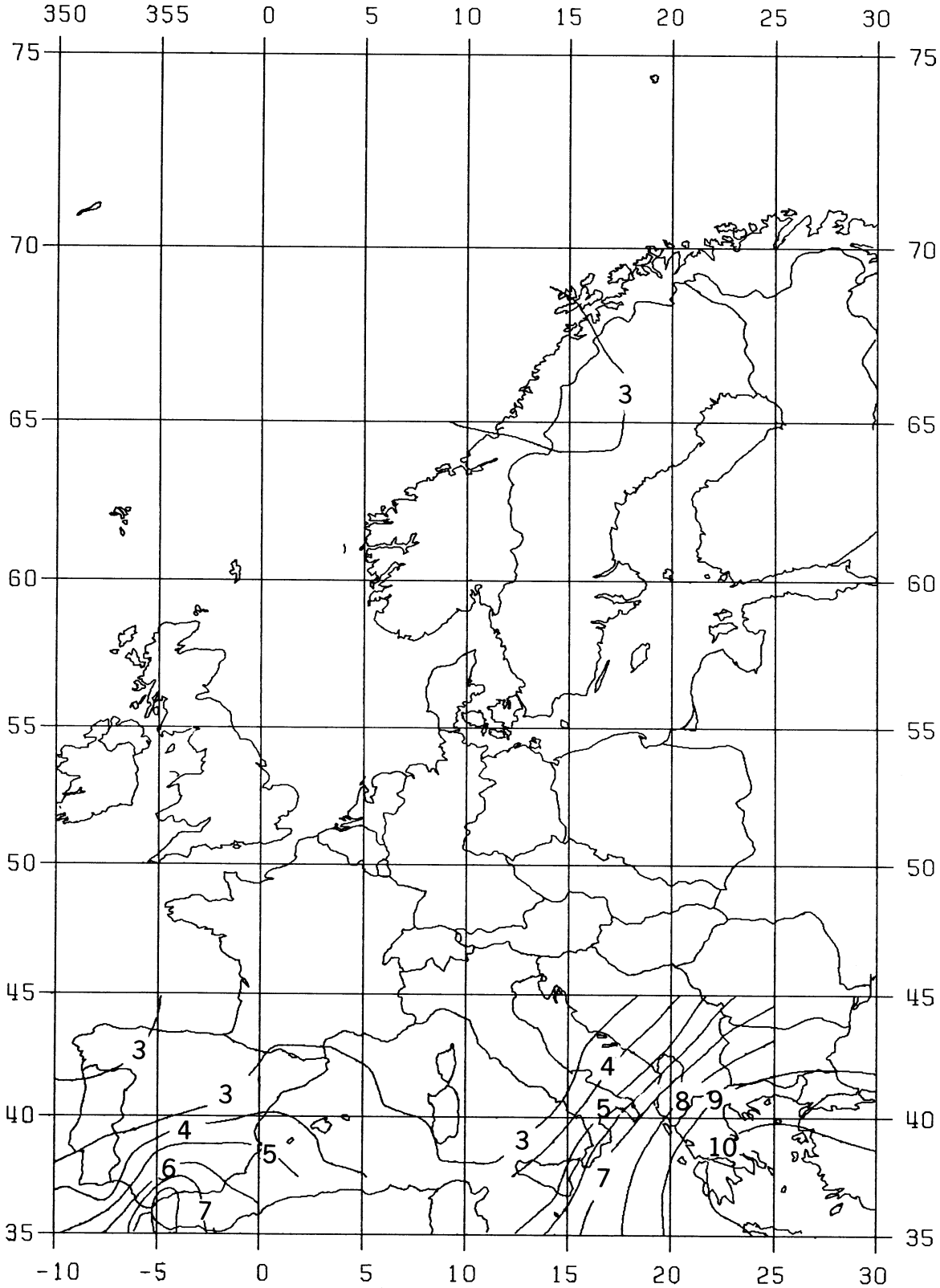

Figure 27.7. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (ED 50 Area, Western Europe), Latitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

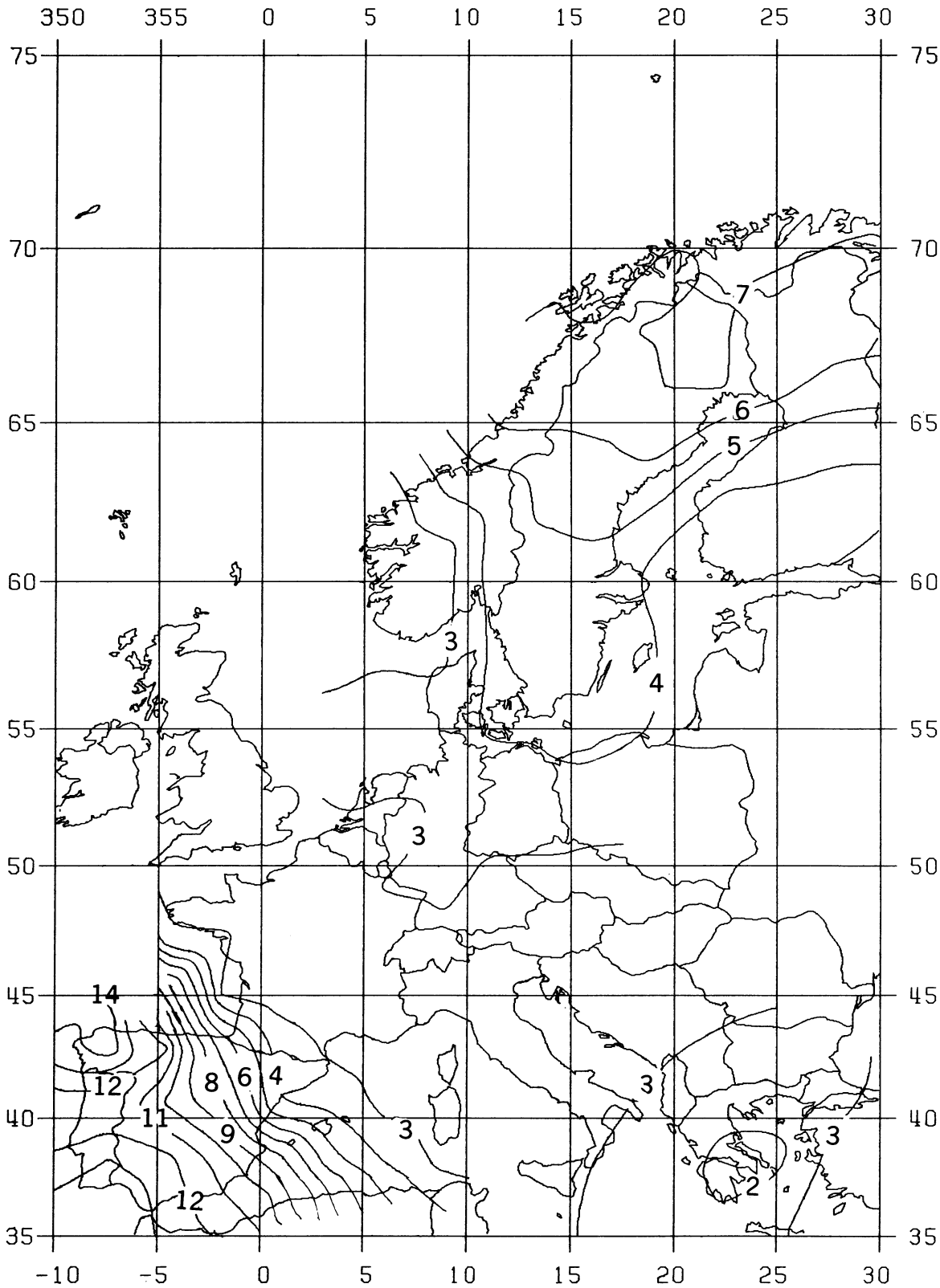

Figure 27.8. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (ED 50 Area, Western Europe), Longitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

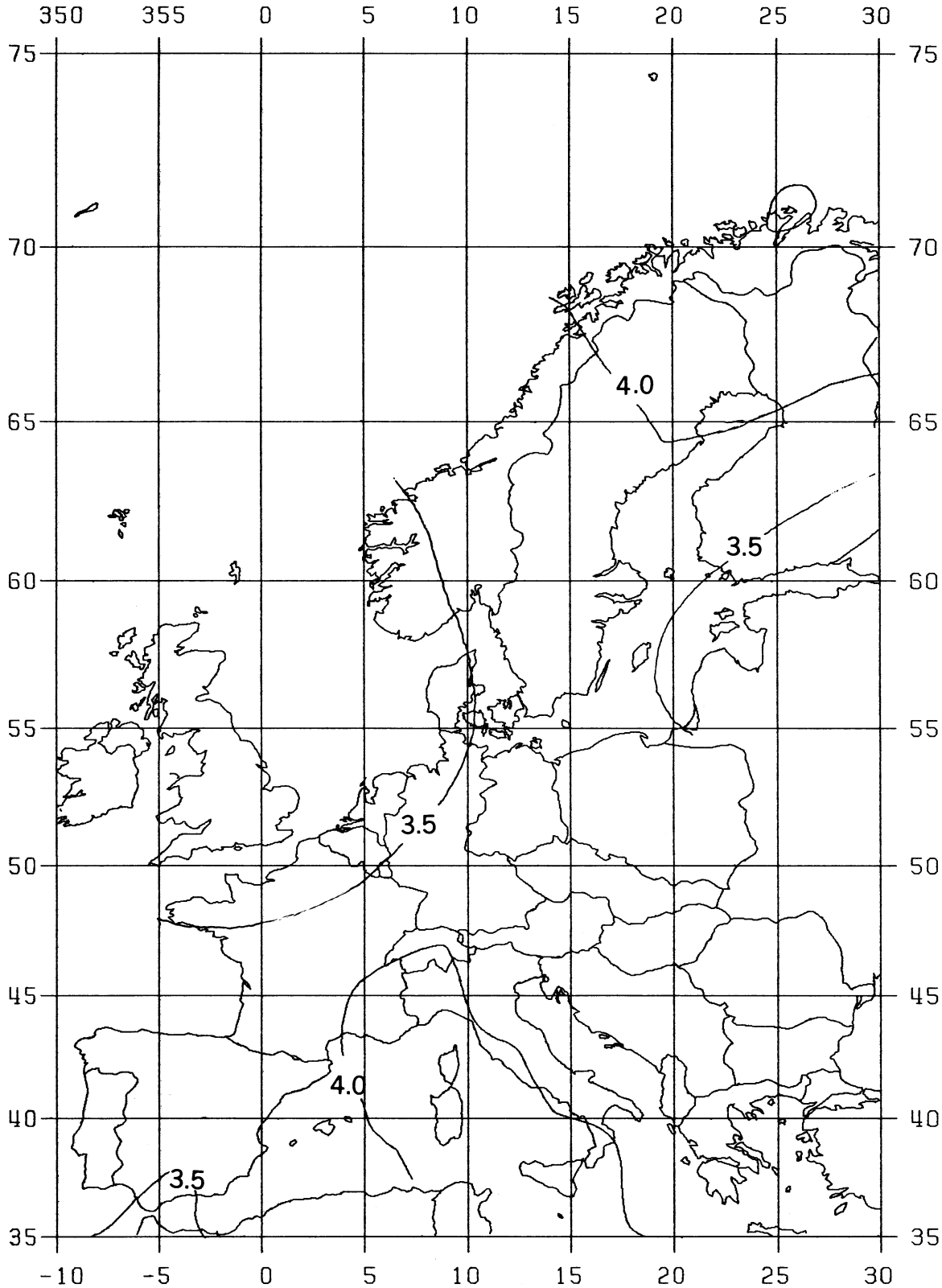

Figure 27.9. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (ED 50 Area, Western Europe), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 0.5 Meter)

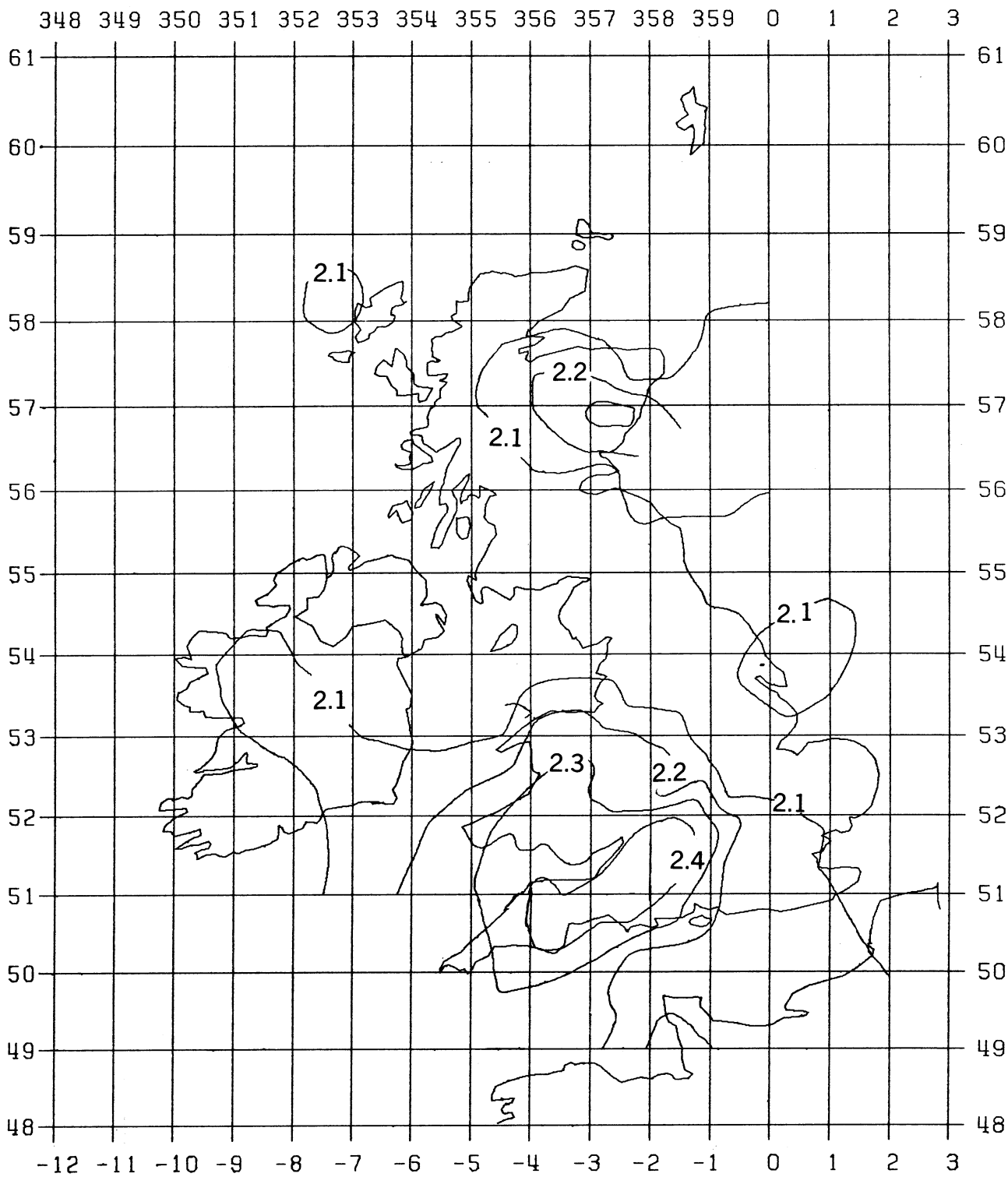

Figure 27.10. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (ED 50 Area, UK/Ireland), Latitude Determined Using Mean Datum Shifts (Contour Interval = 0.1 Meter)

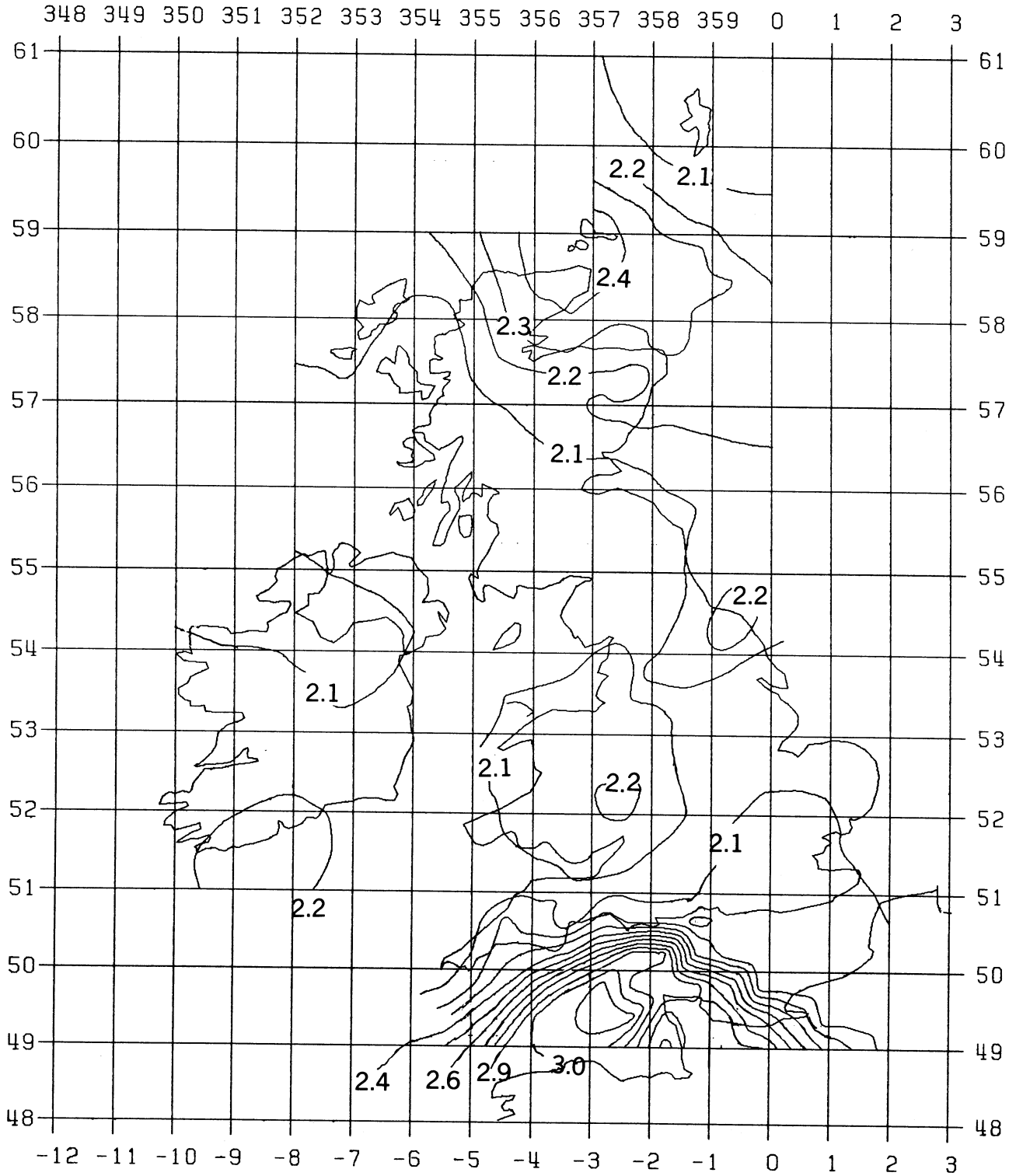

Figure 27.11. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (ED 50 Area, UK/Ireland), Longitude Determined Using Mean Datum Shifts (Contour Interval = 0.1 Meter)

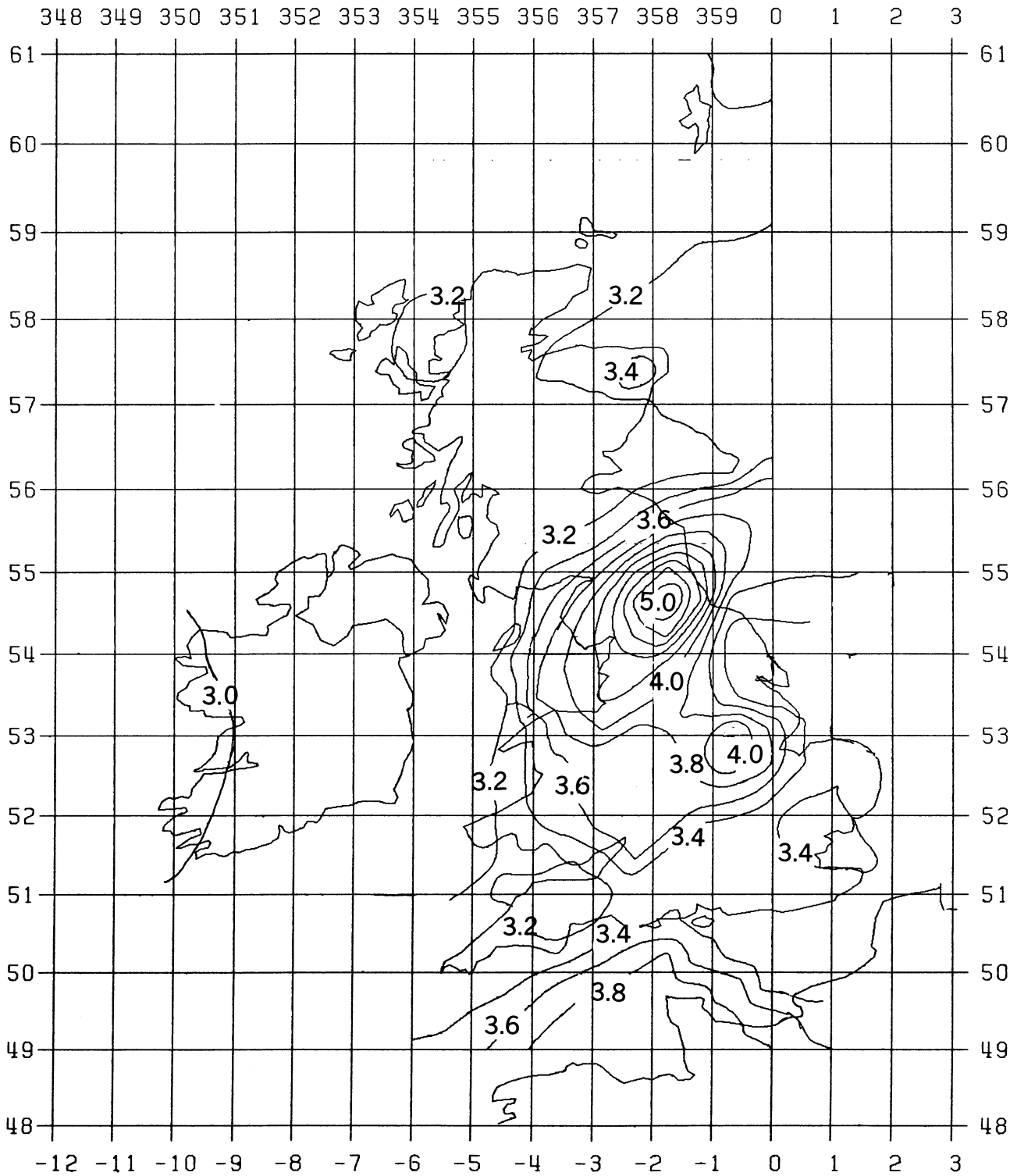

Figure 27.12. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (ED 50 Area, UK/Ireland), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 0.2 Meter)

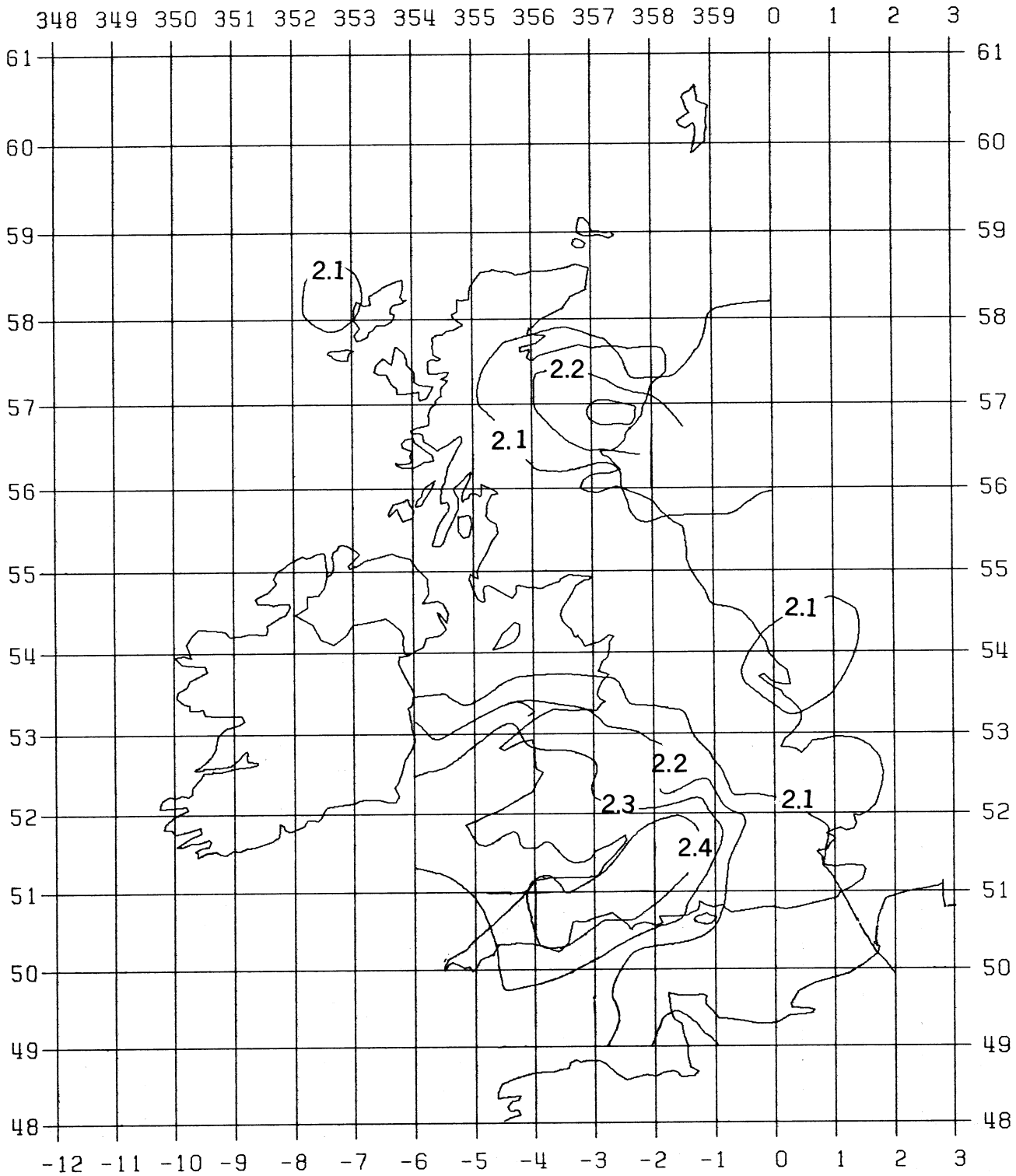

Figure 27.13. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (ED 50 Area, UK Only), Latitude Determined Using Mean Datum Shifts (Contour Interval = 0.1 Meter)

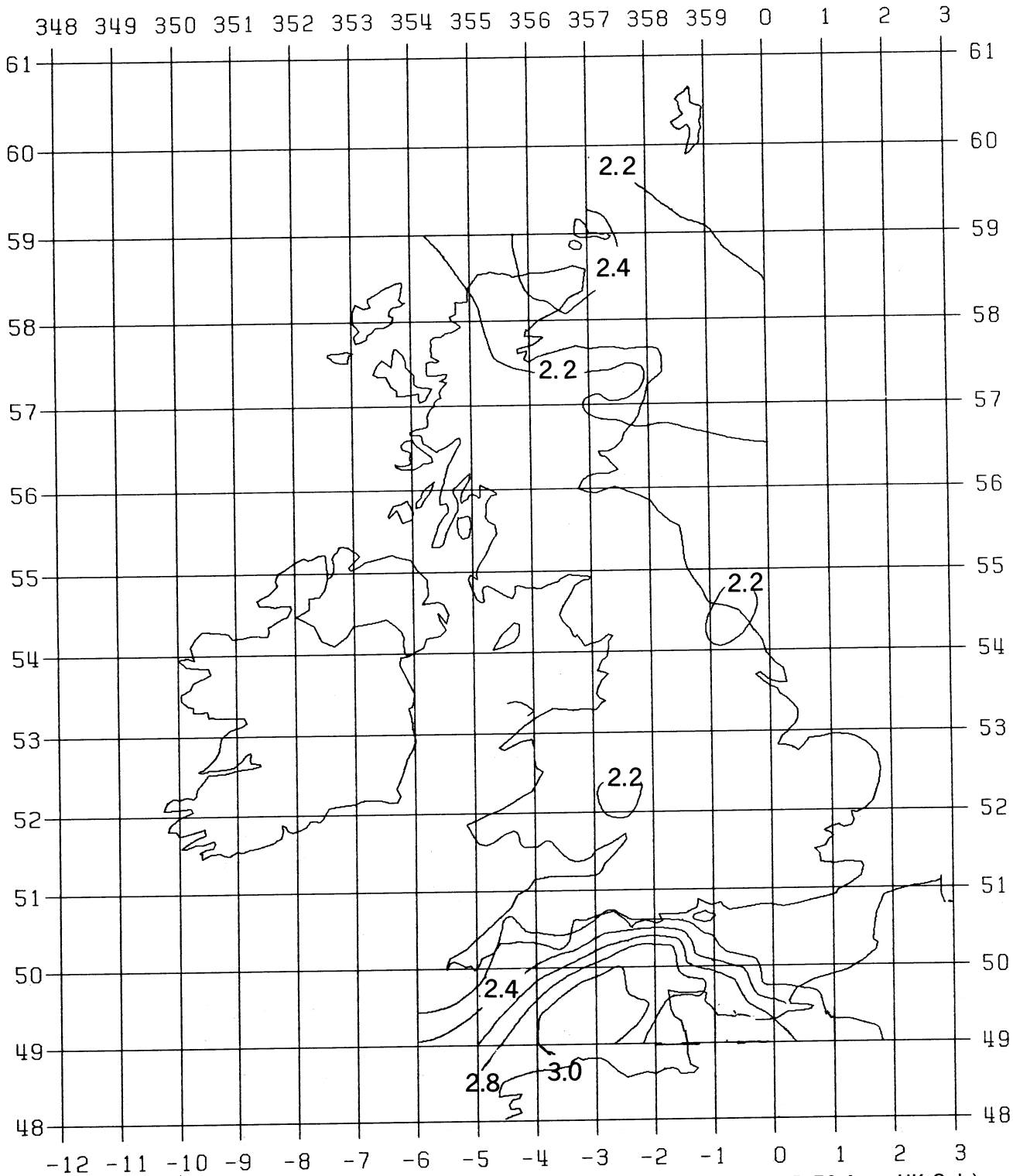

Figure 27.14. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (ED 50 Area, UK Only), Longitude Determined Using Mean Datum Shifts (Contour Interval = 0.2 Meter)

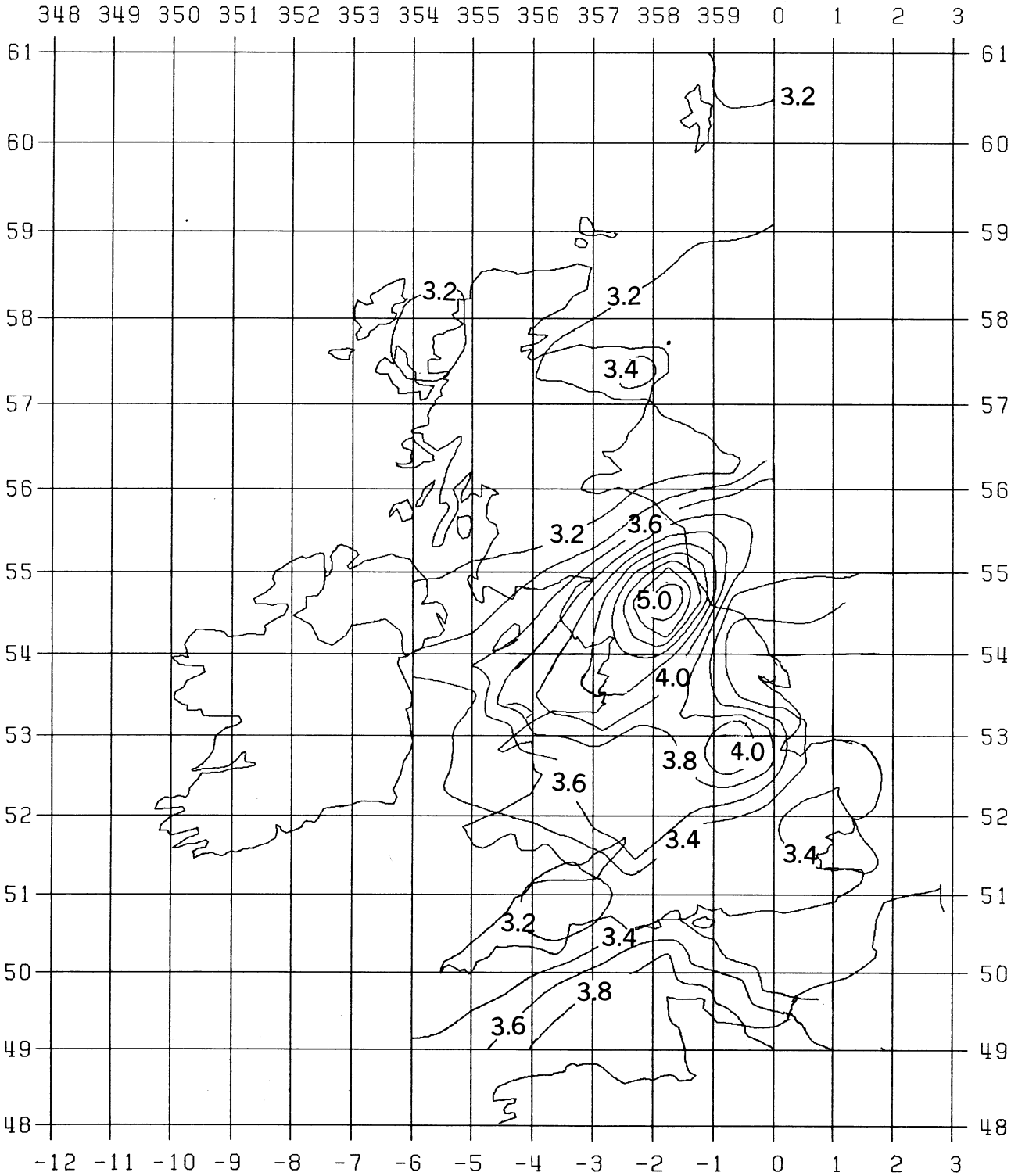

Figure 27.15. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (ED 50 Area, UK Only), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 0.2 Meter)

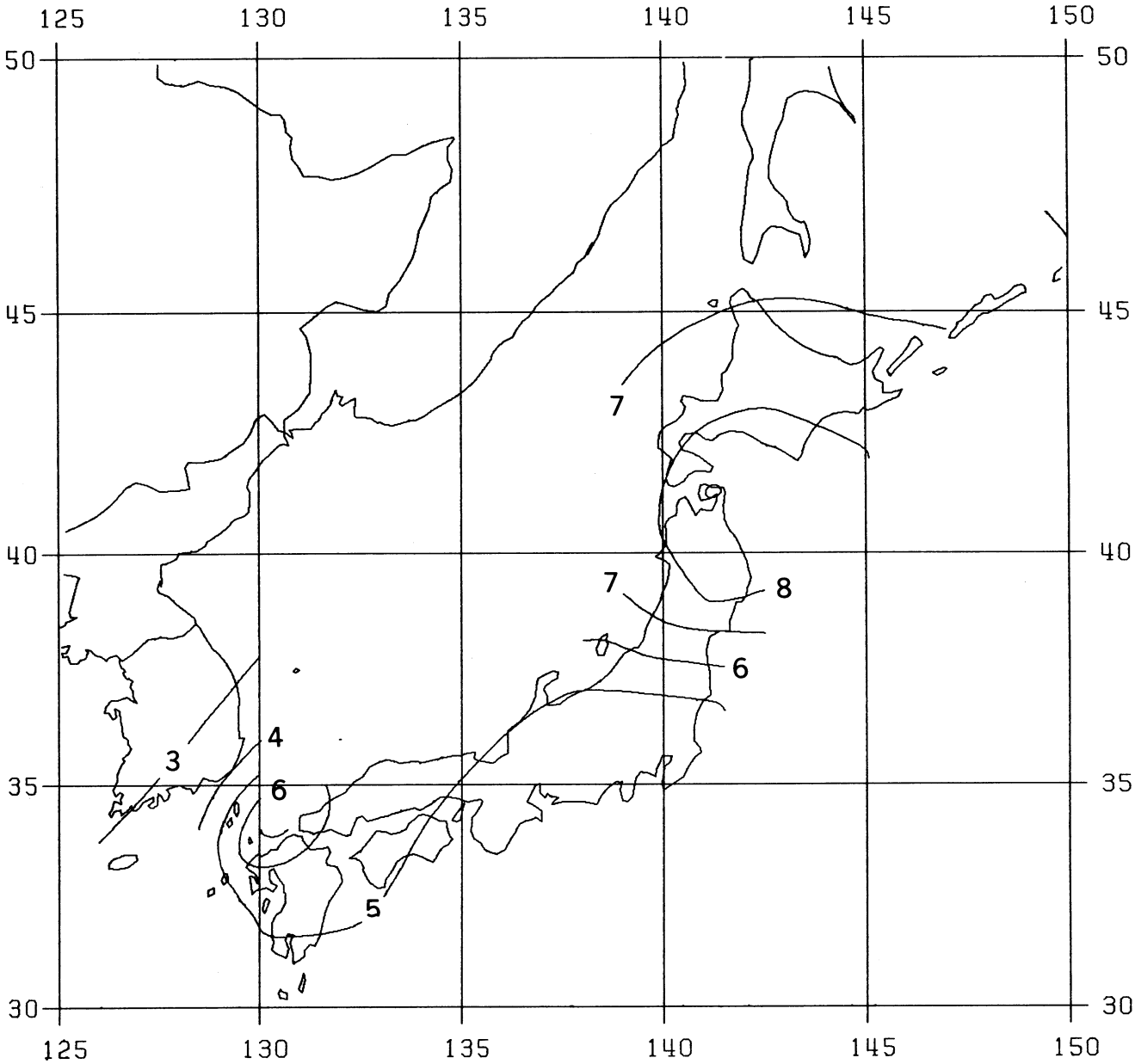

Figure 27.16. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (TD Area), Latitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

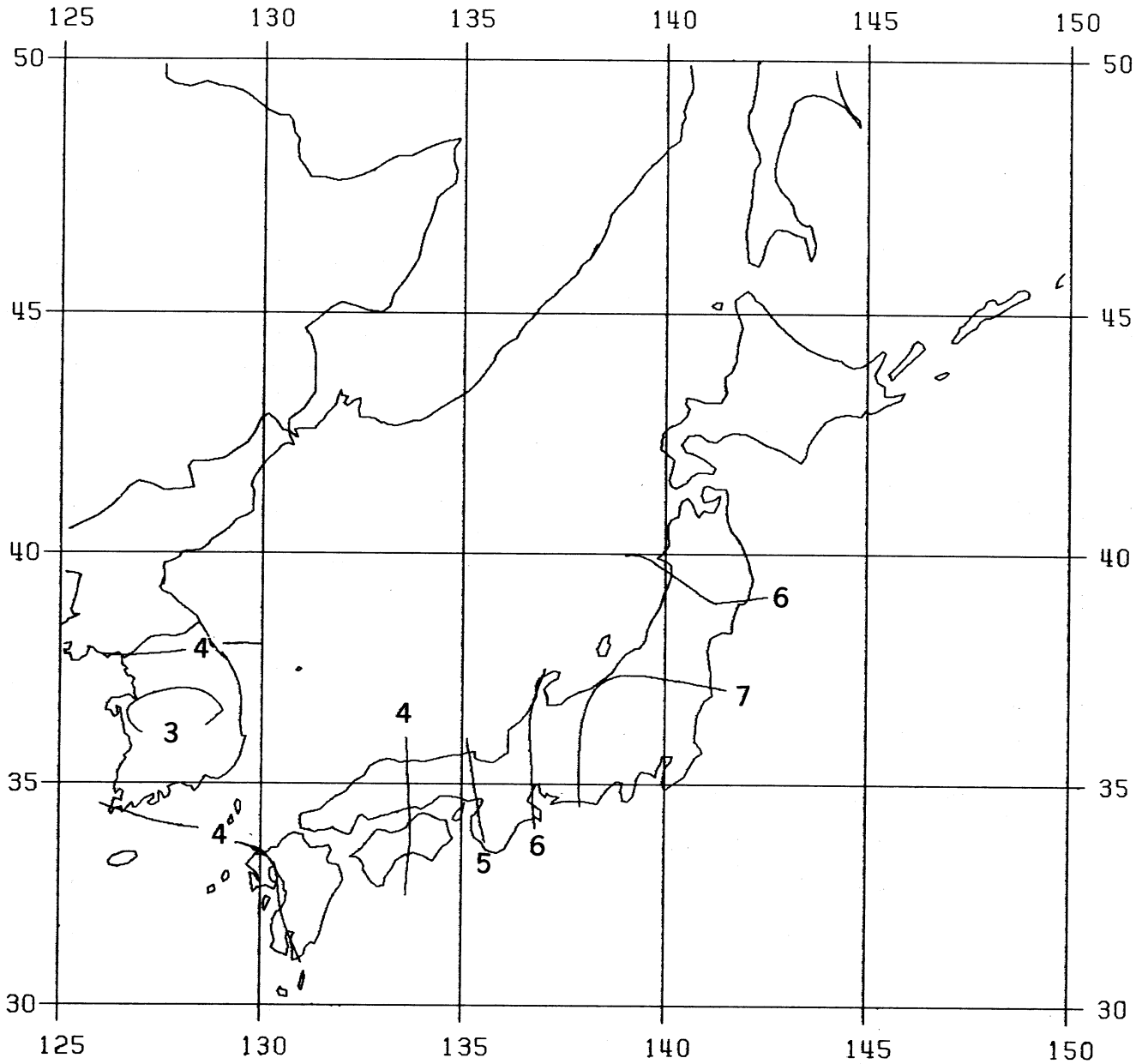

Figure 27.17. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (TD Area), Longitude Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

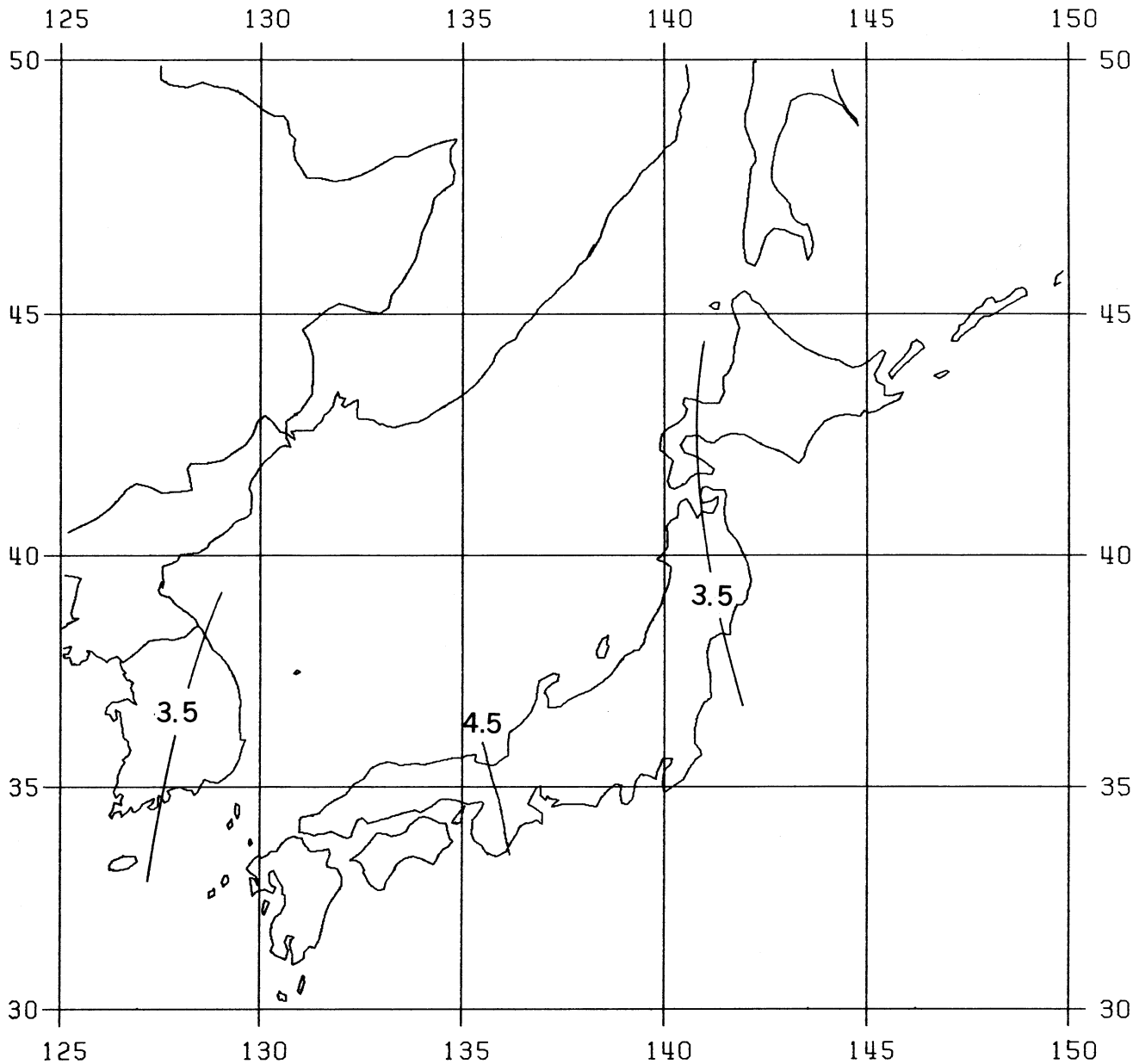

Figure 27.18. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (TD Area), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 1 Meter)

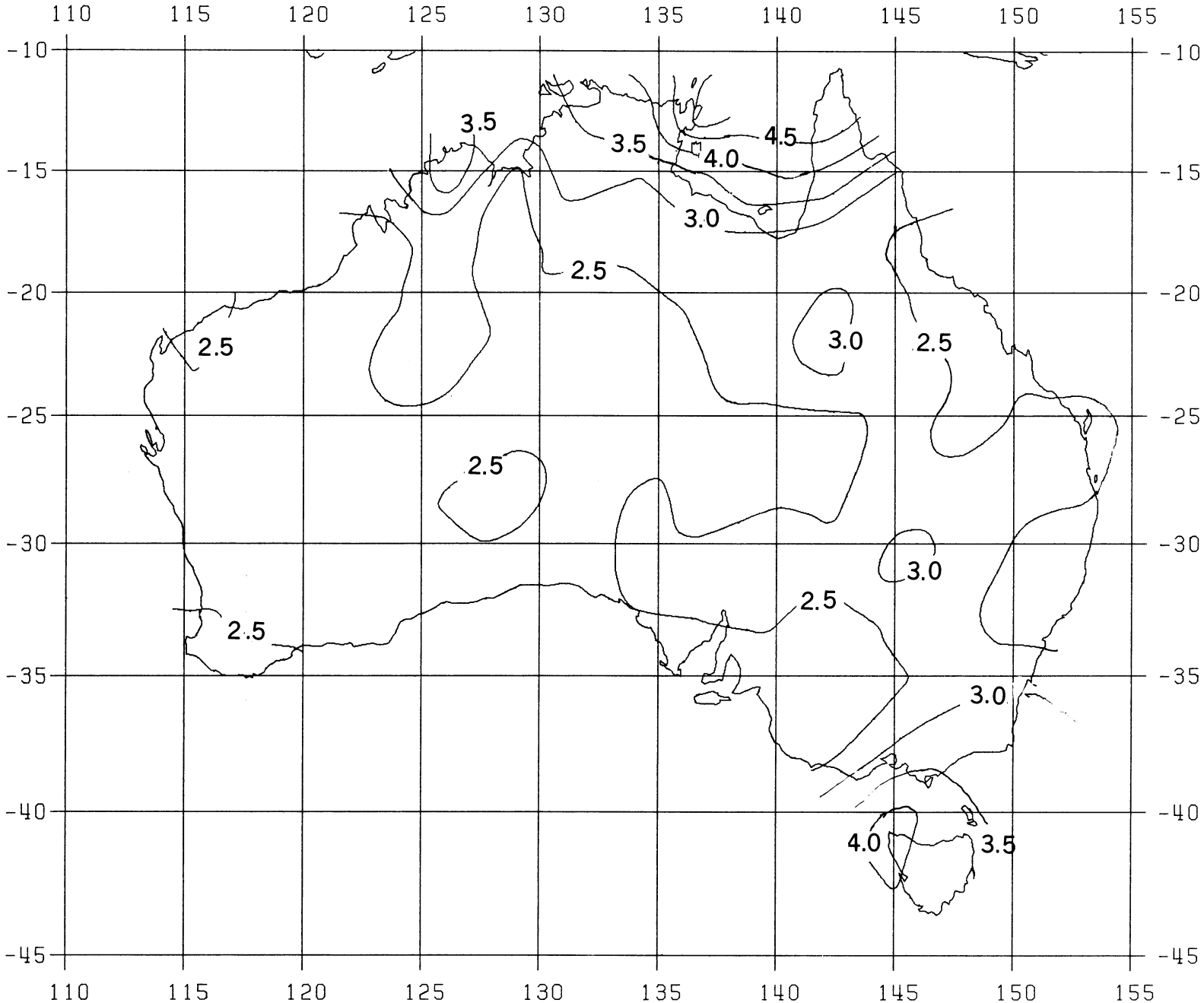

Figure 27.19. . Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (AGD 84 Area), Latitude Determined Using Mean Datum Shifts (Contour Interval = 0.5 Meter)

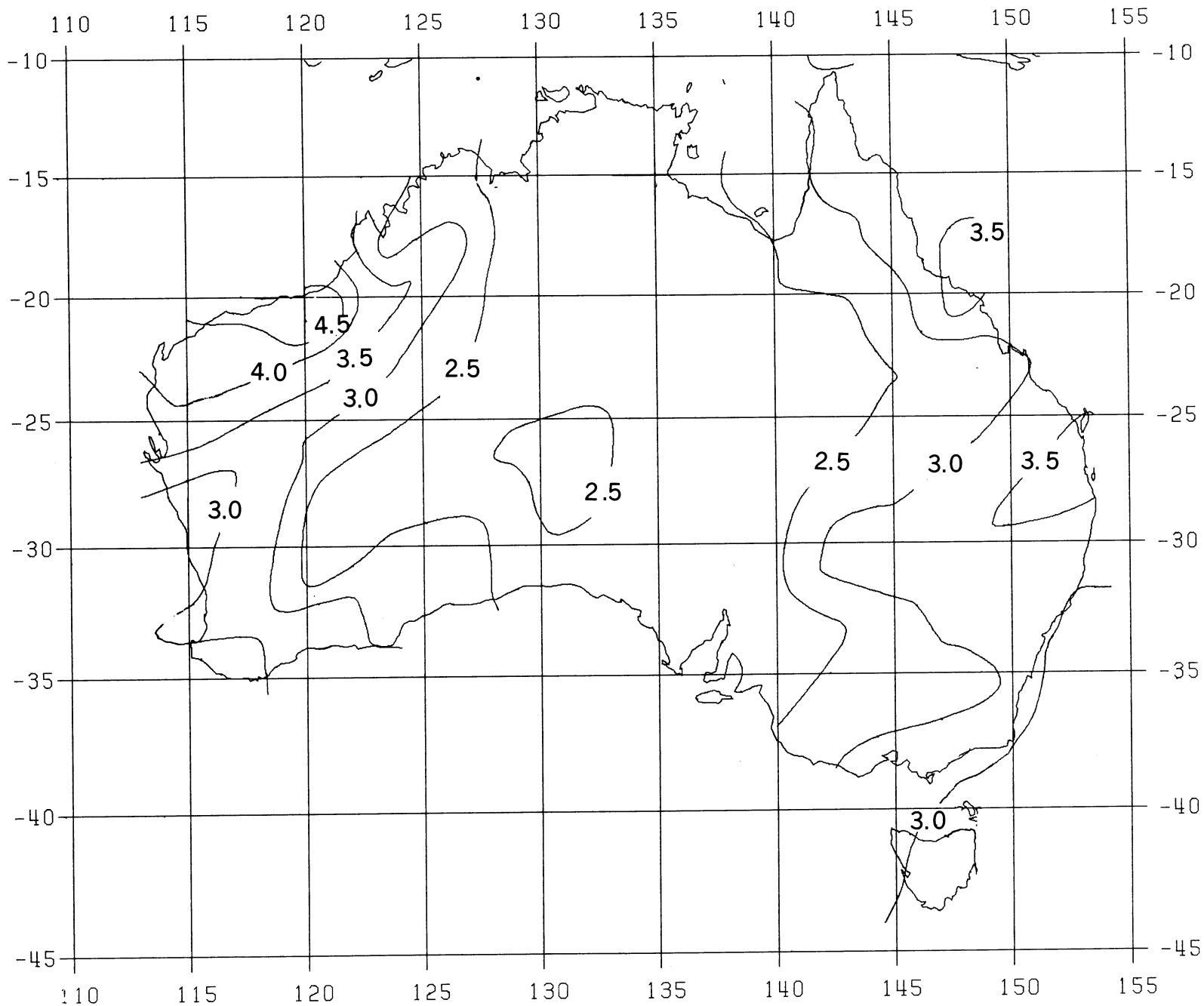

Figure 27.20. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (AGD 84 Area), Longitude Determined Using Mean Datum Shifts (Contour Interval = 0.5 Meter)

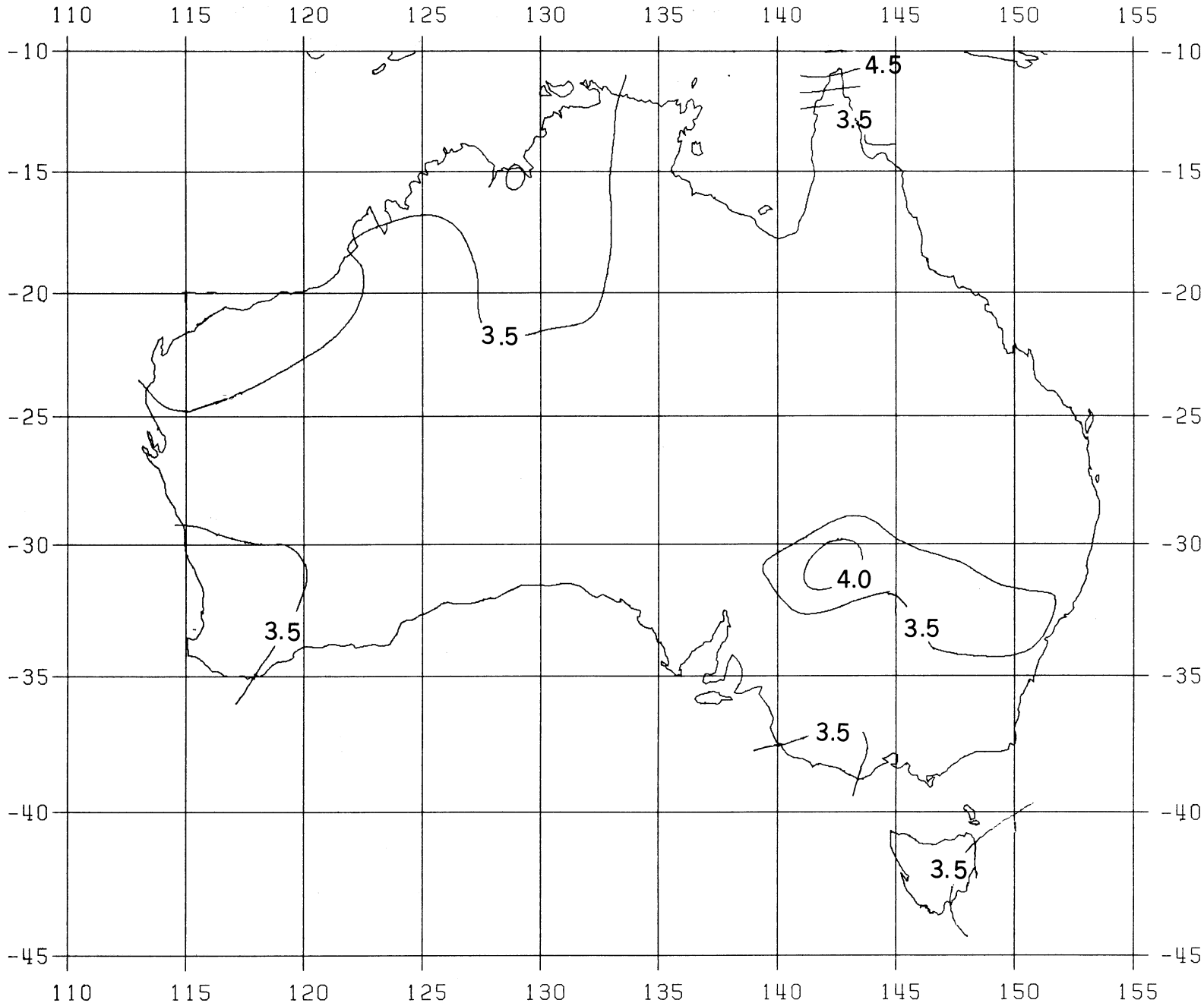

Figure 27.21. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (AGD 84 Area), Geodetic Height Determined Using Mean Datum Shifts (Contour Interval = 0.5 Meter)

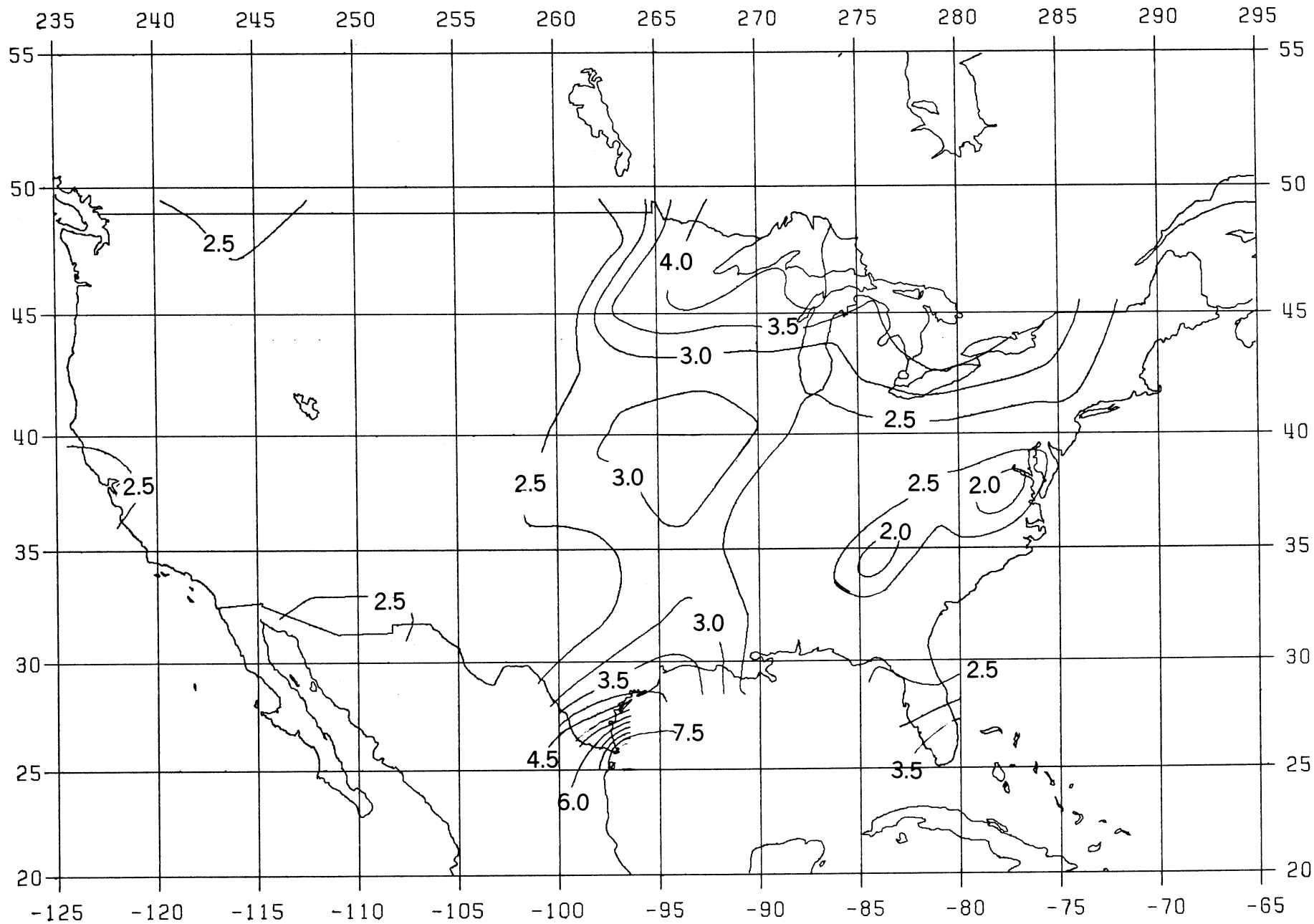

Figure 27.22. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (NAD 27 Area, CONUS), Latitude Determined Using Datum Transformation MREs (Contour Interval = 0.5 Meter)

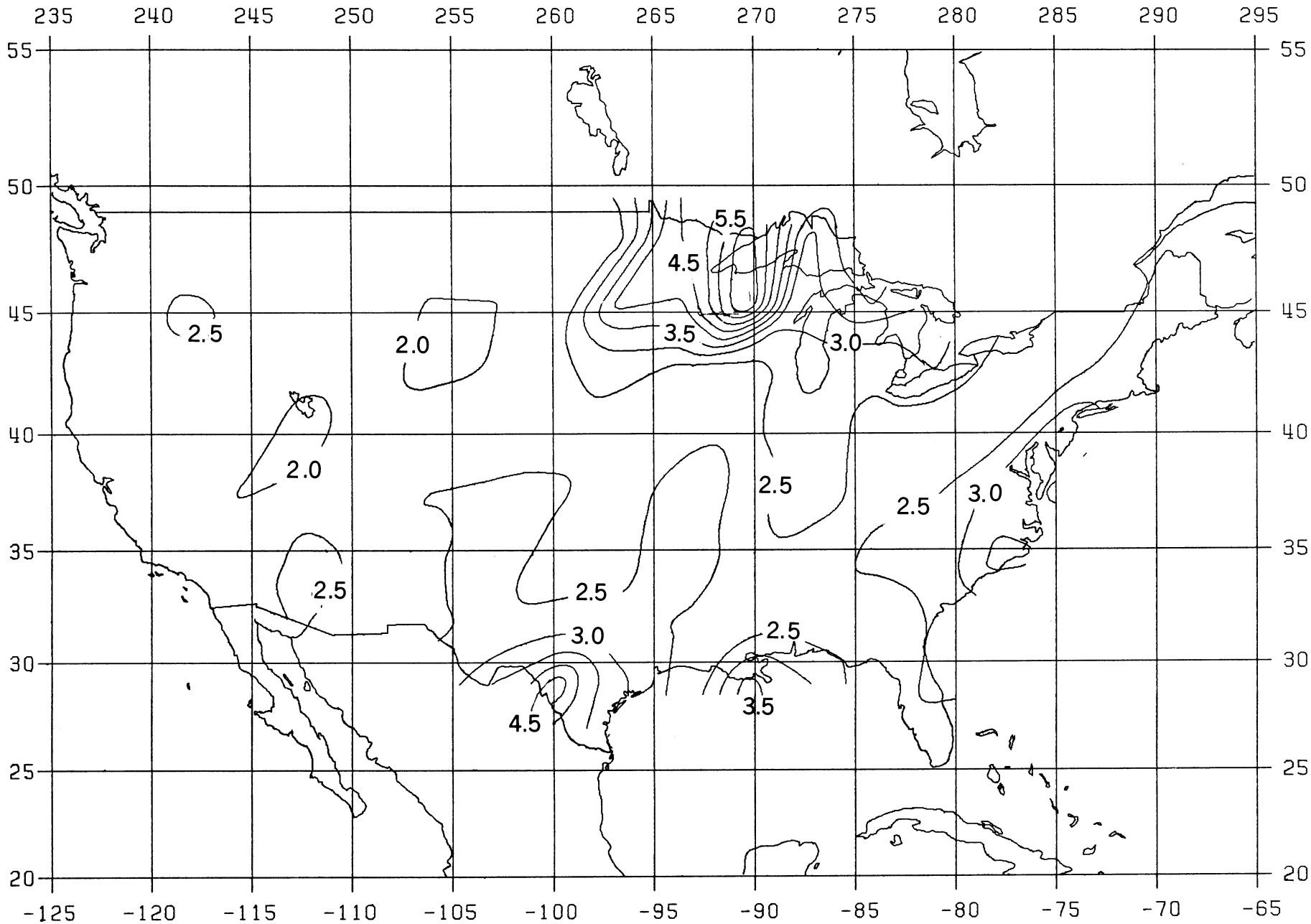

Figure 27.23. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (NAD 27 Area, CONUS), Longitude Determined Using Datum Transformation MREs (Contour Interval = 0.5 Meter)

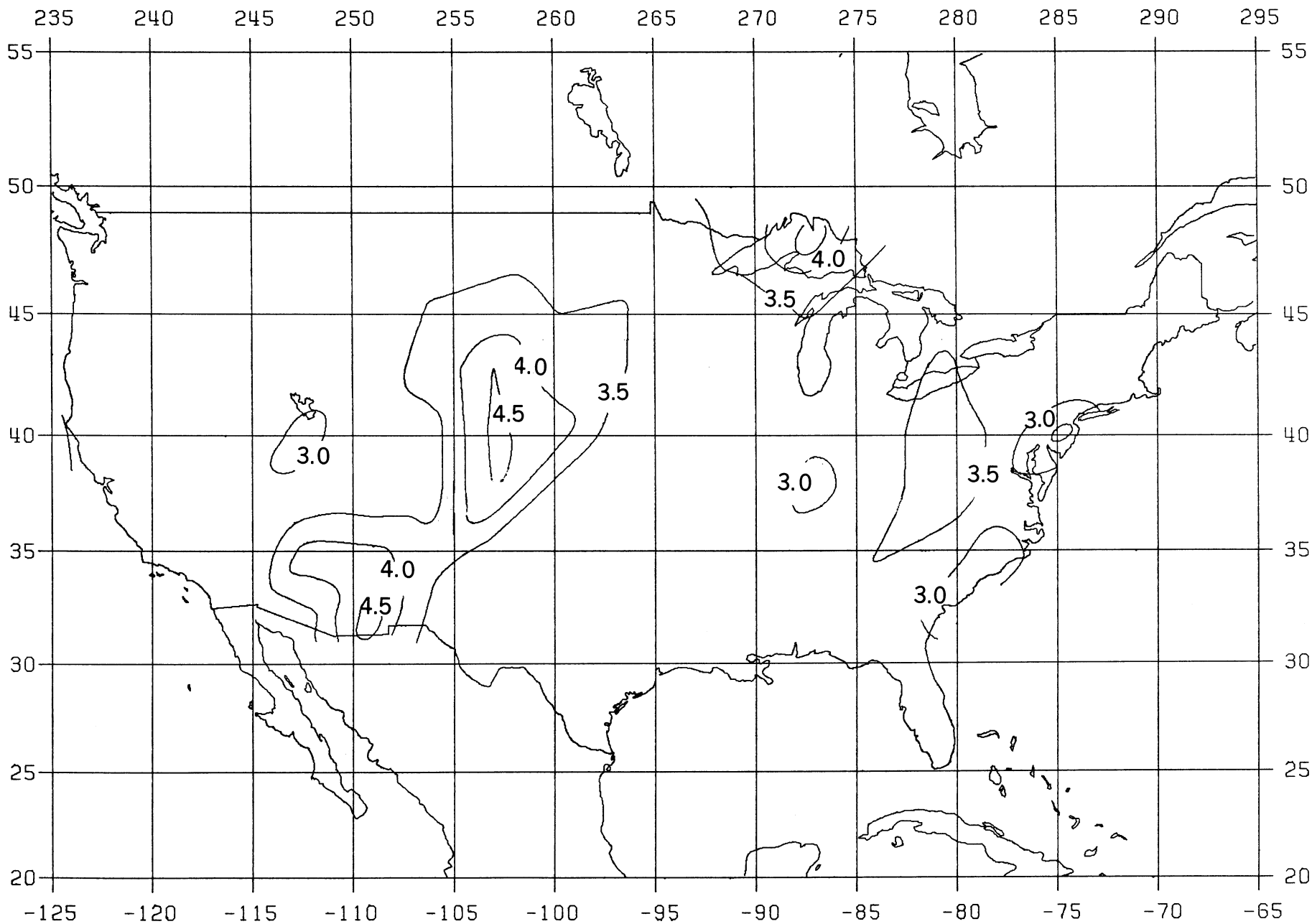

Figure 27.24. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (NAD 27 Area, CONUS), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 0.5 Meter)

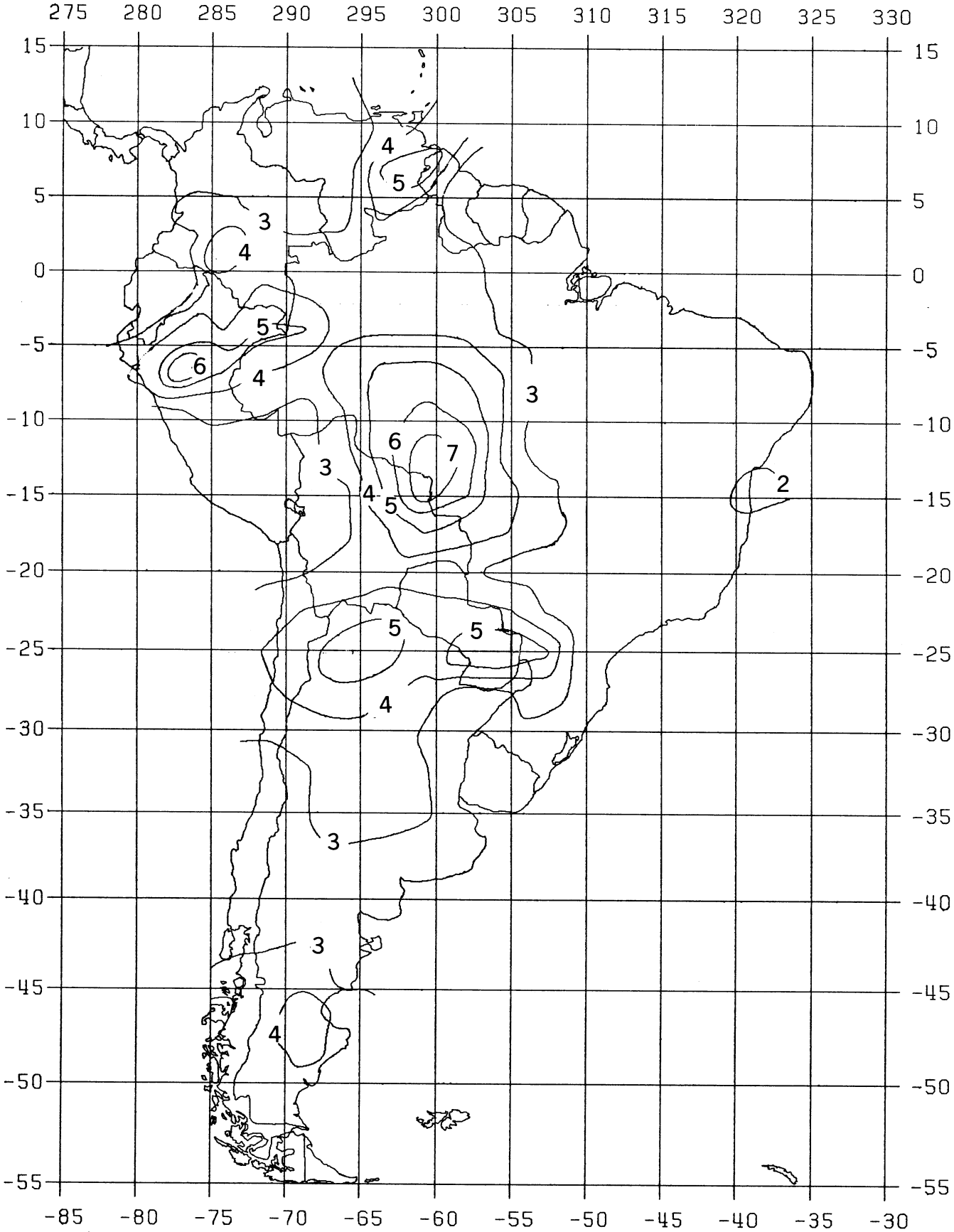

Figure 27.25. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (SAD 69 Area), Latitude Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

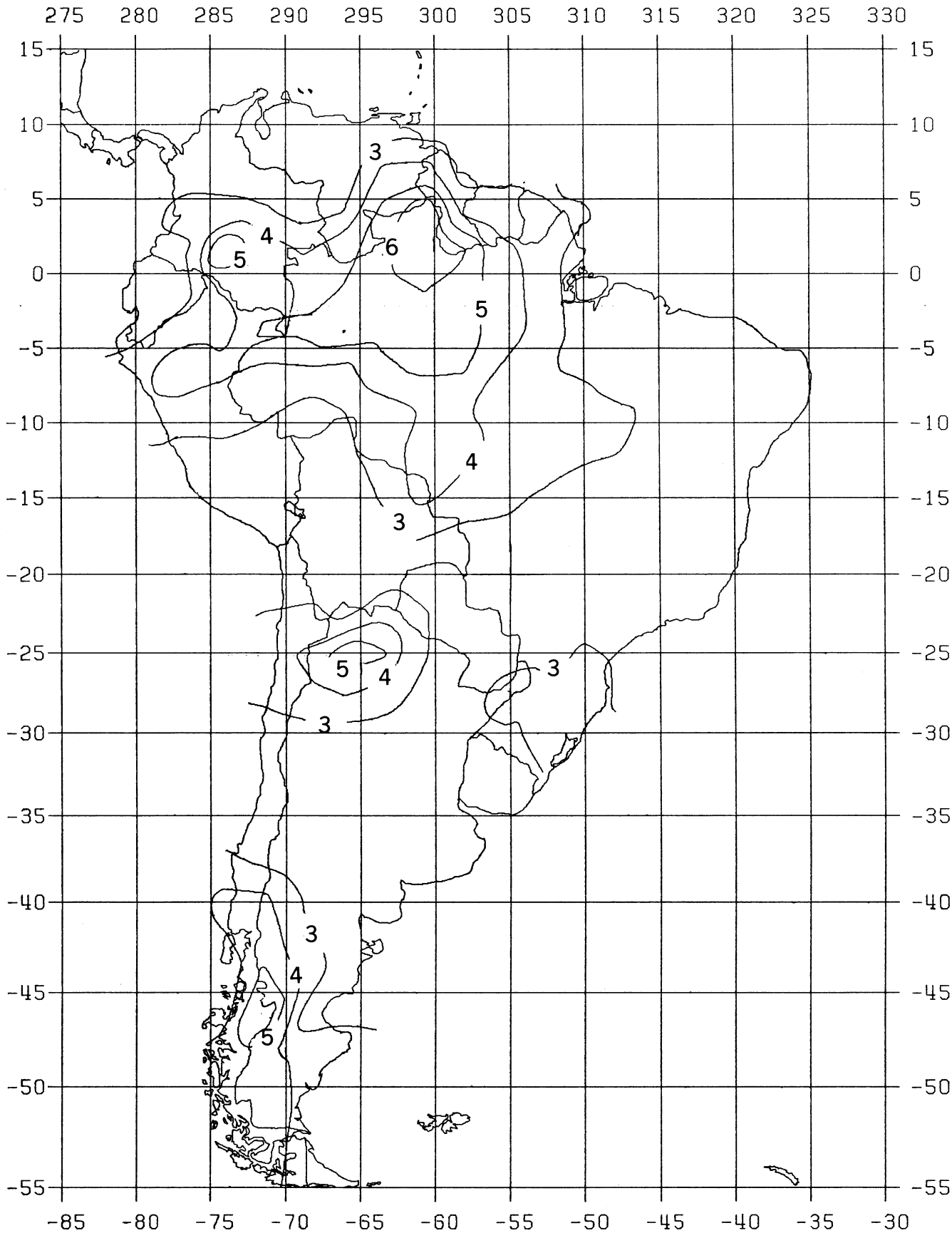

Figure 27.26. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (SAD 69 Area), Longitude Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

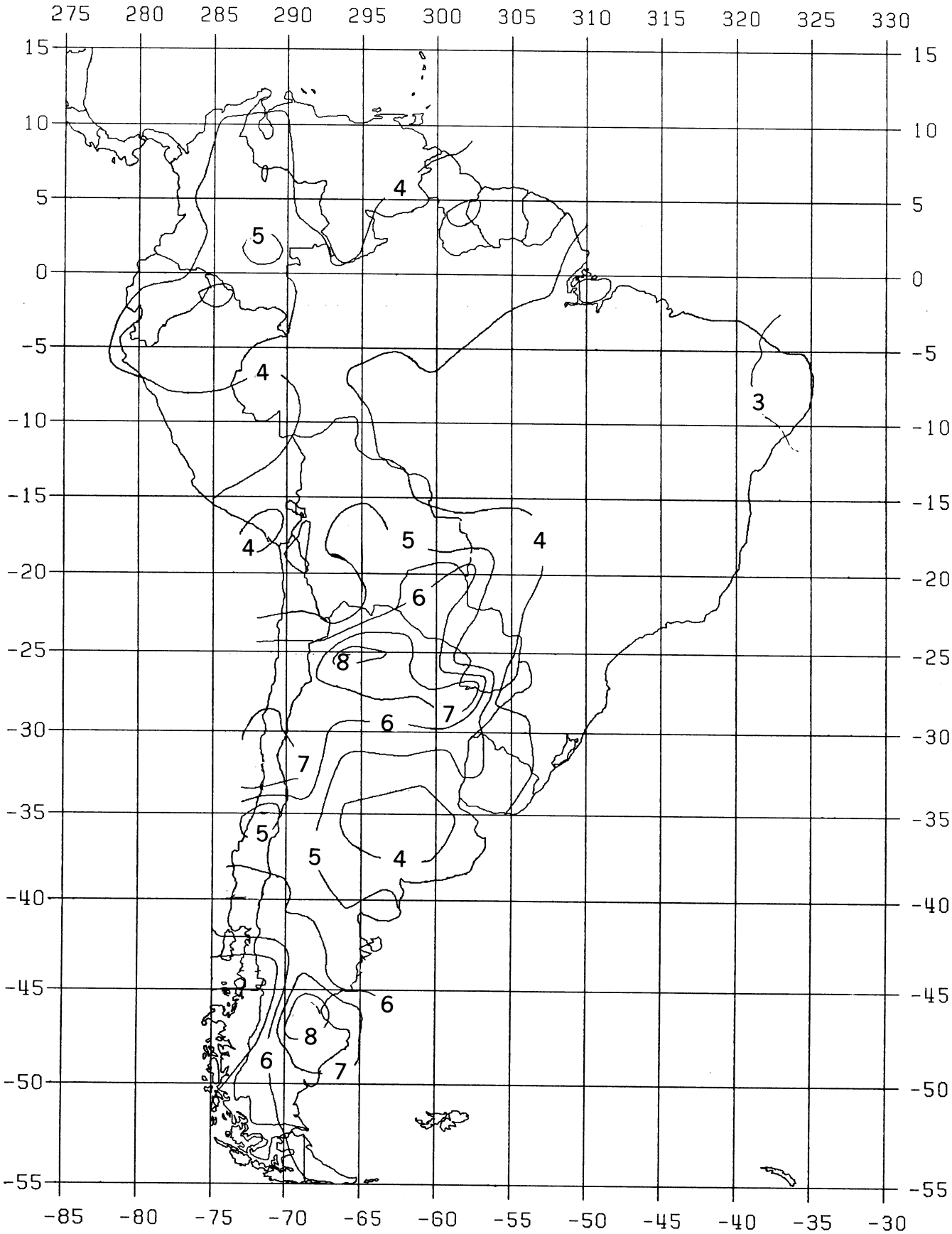

Figure 27.27. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (SAD 69 Area), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

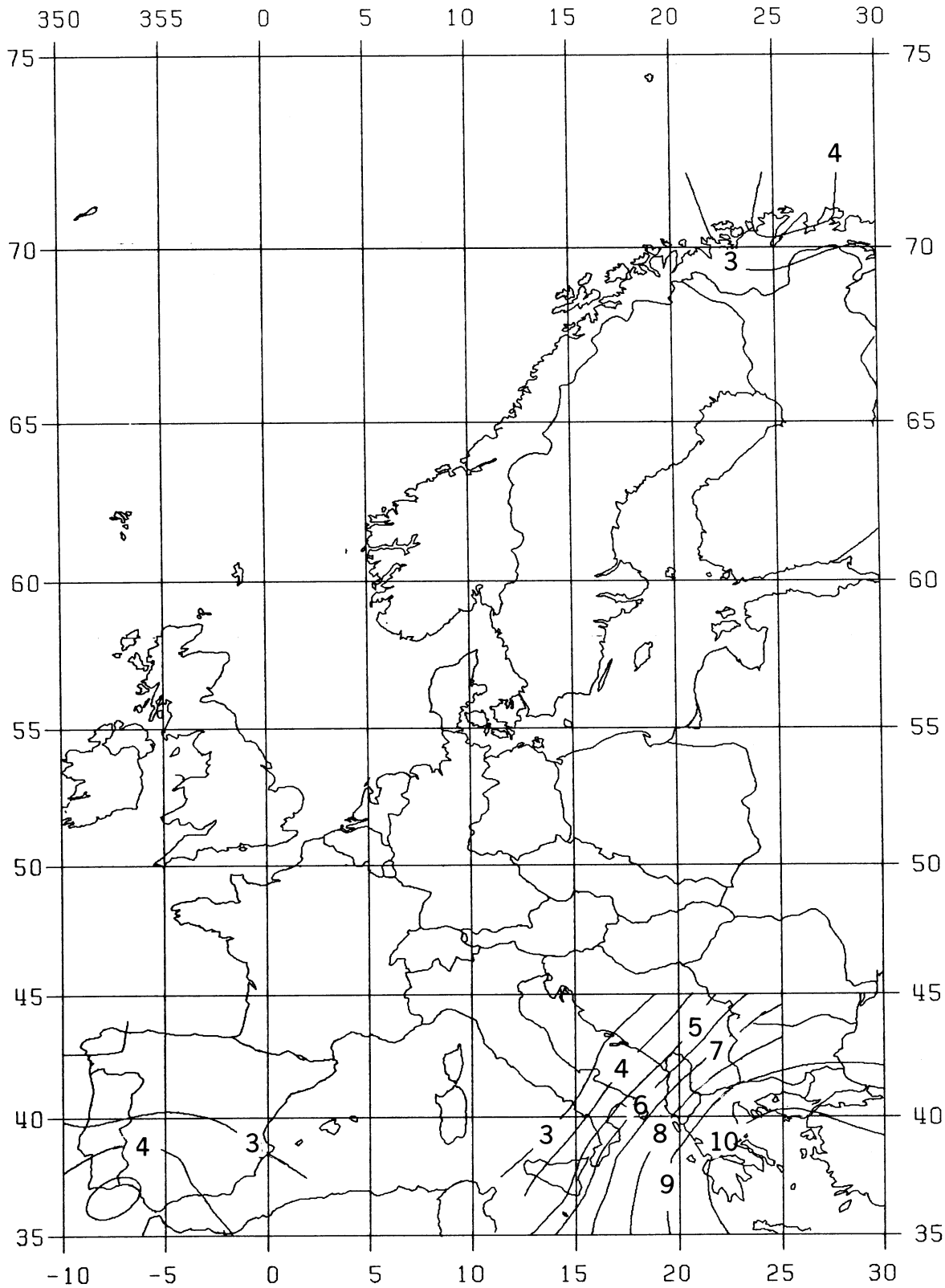

Figure 27.28. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (ED 50 Area, Western Europe), Latitude Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

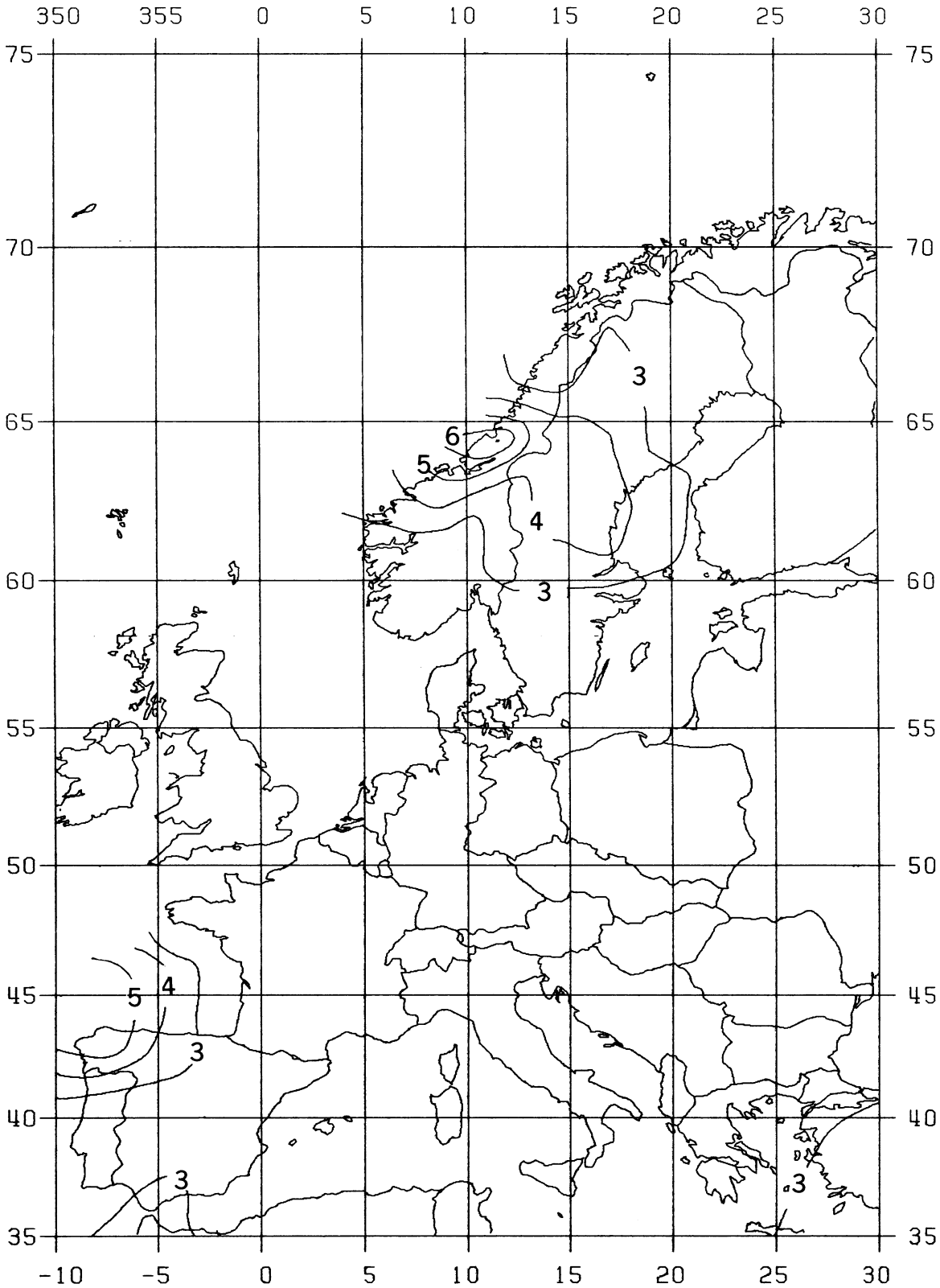

Figure 27.29. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (ED 50 Area, Western Europe), Longitude Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

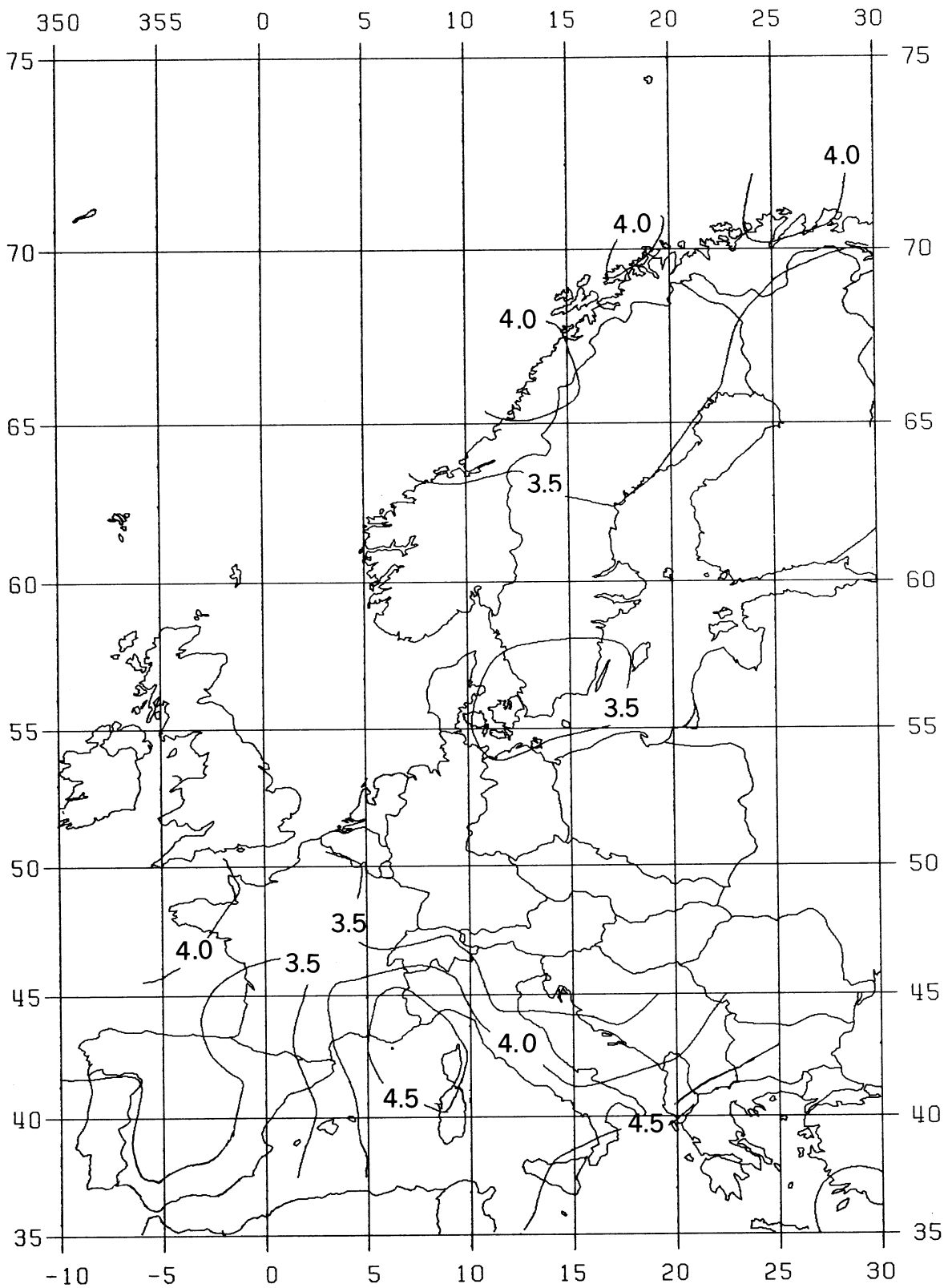

Figure 27.30. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (ED 50 Area, Western Europe), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 0.5 Meter)

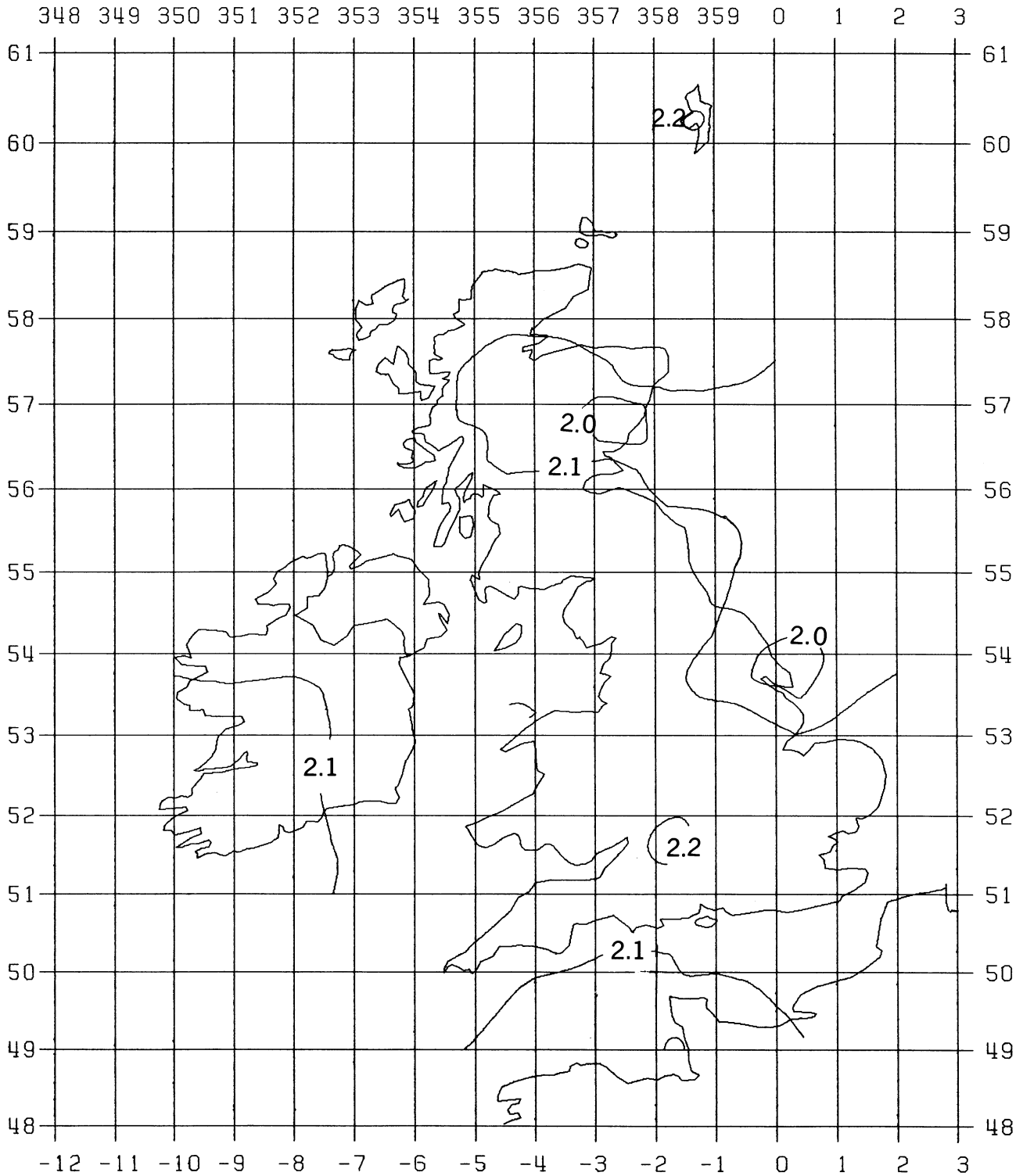

Figure 27.31. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (ED 50 Area, UK/Ireland), Latitude Determined Using Datum Transformation MREs (Contour Interval = 0.1 Meter)

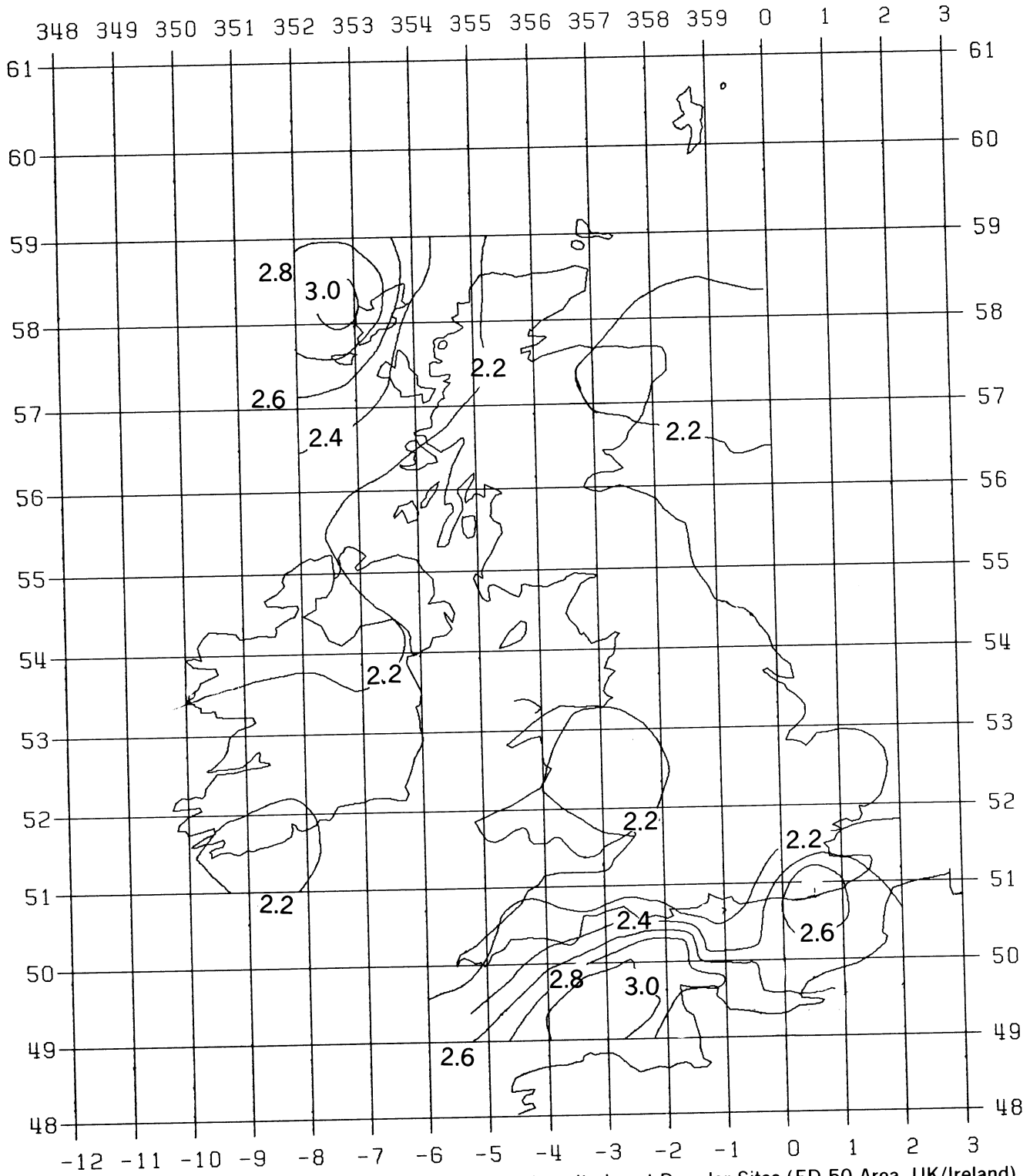

Figure 27.32. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (ED 50 Area, UK/Ireland), Longitude Determined Using Datum Transformation MREs (Contour Interval = 0.2 Meter)

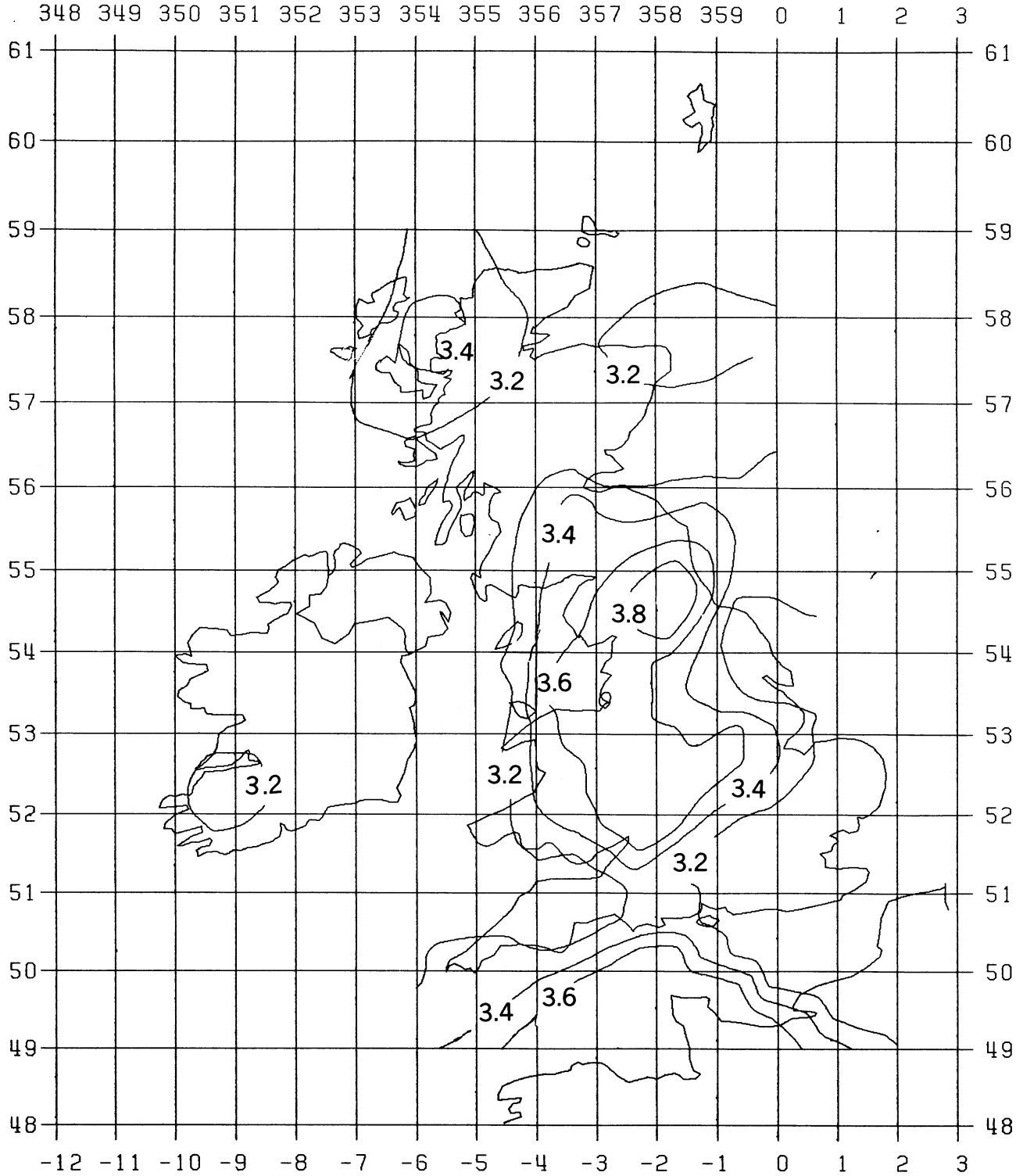

Figure 27.33. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (ED 50 Area, UK/Ireland), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 0.2 Meter)

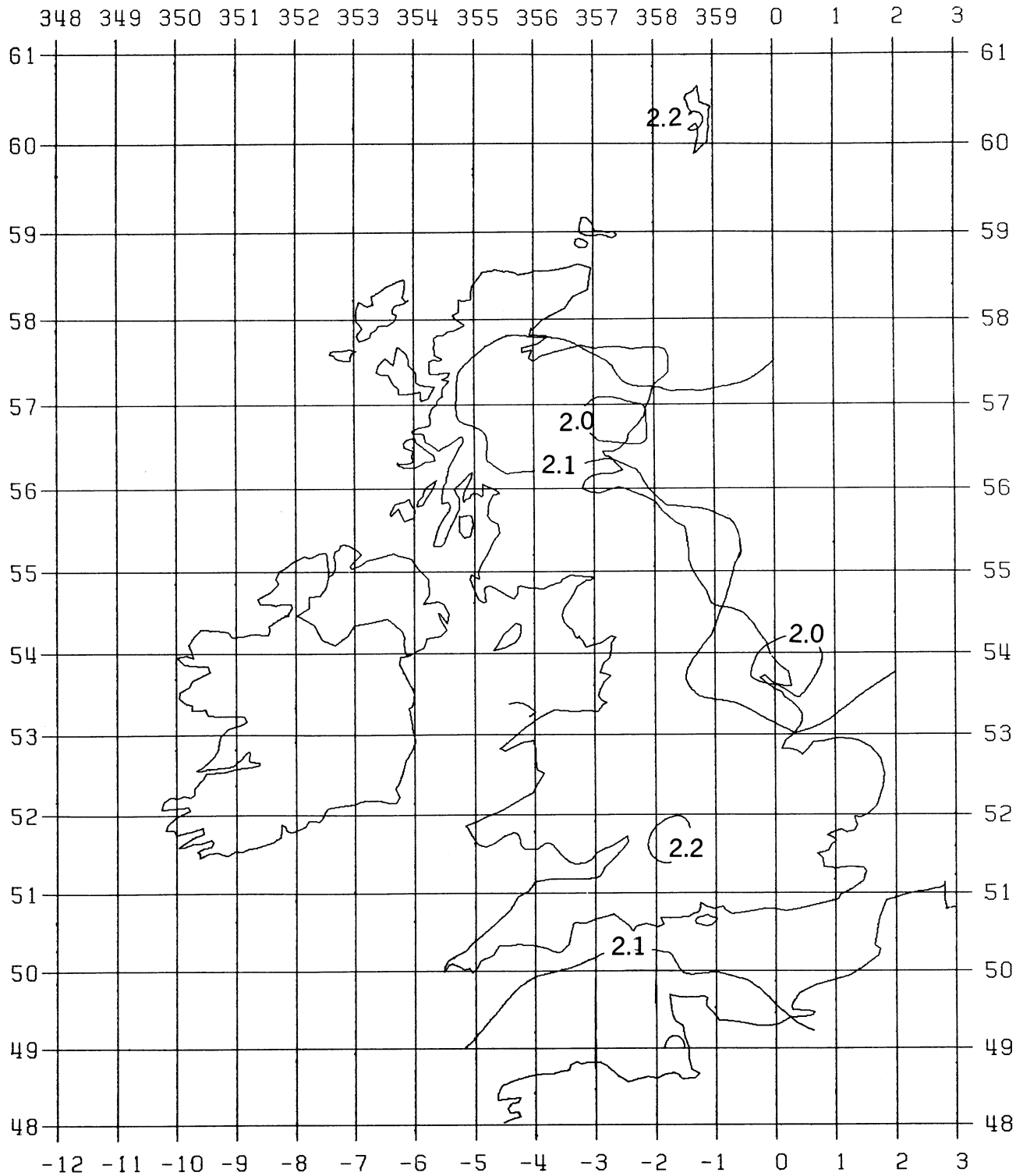

Figure 27.34. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (ED 50 Area, UK Only), Latitude Determined Using Datum Transformation MREs (Contour Interval = 0.1 Meter)

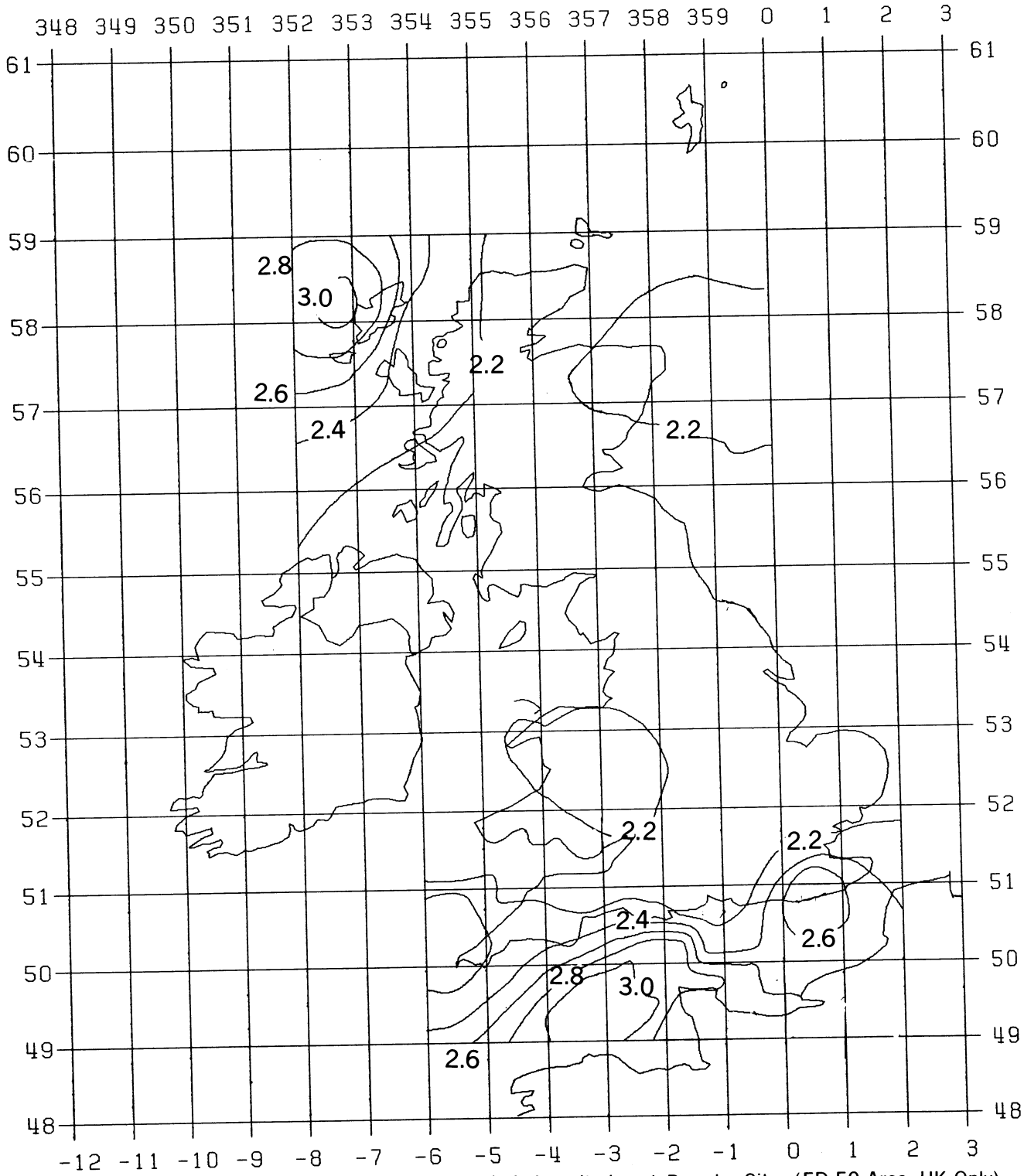

Figure 27.35. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (ED 50 Area, UK Only), Longitude Determined Using Datum Transformation MREs (Contour Interval = 0.2 Meter)

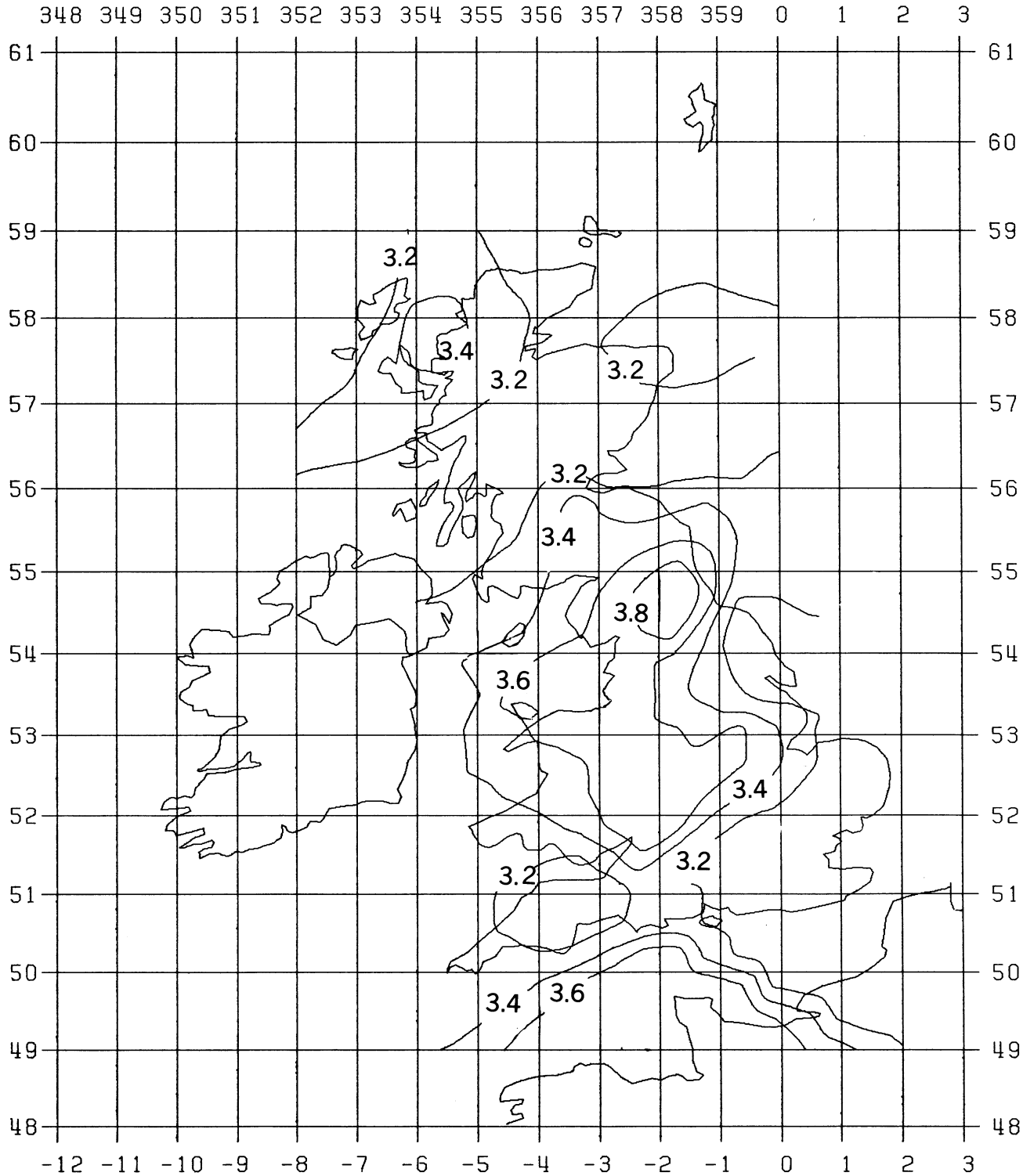

Figure 27.36. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (ED 50 Area, UK Only), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 0.2 Meter)

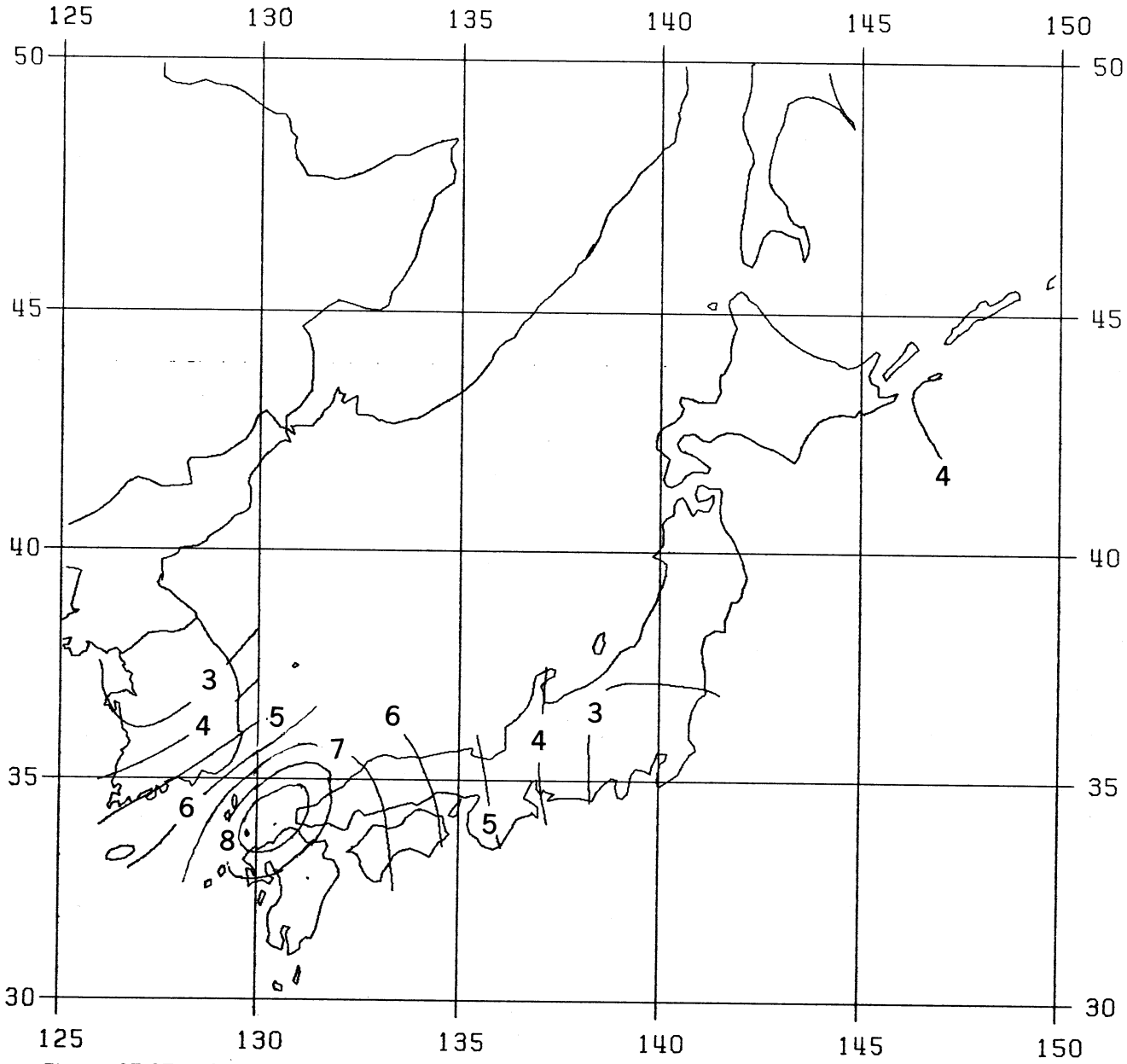

Figure 27.37. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (TD Area), Latitude Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

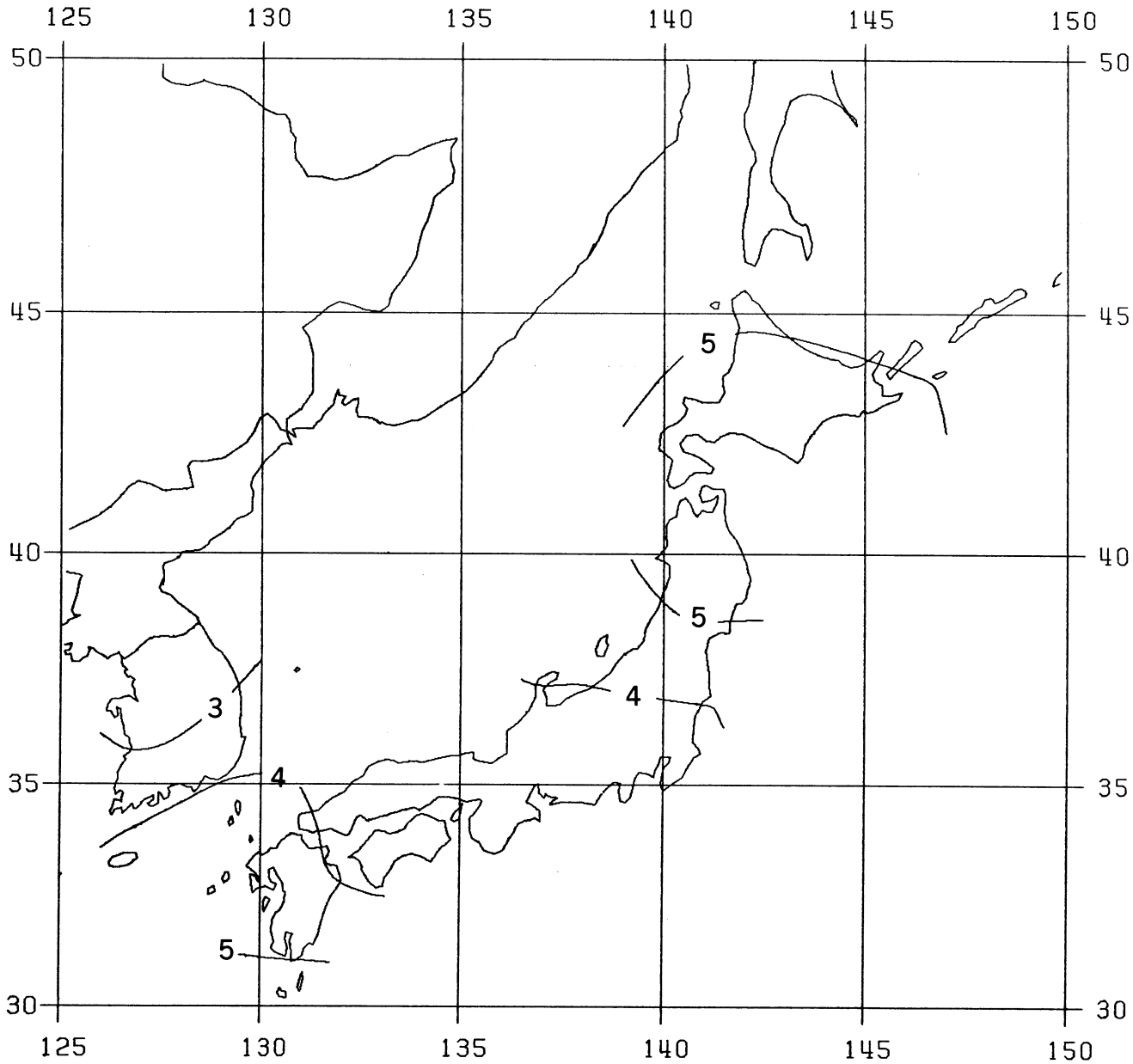

Figure 27.38. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (TD Area), Longitude Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

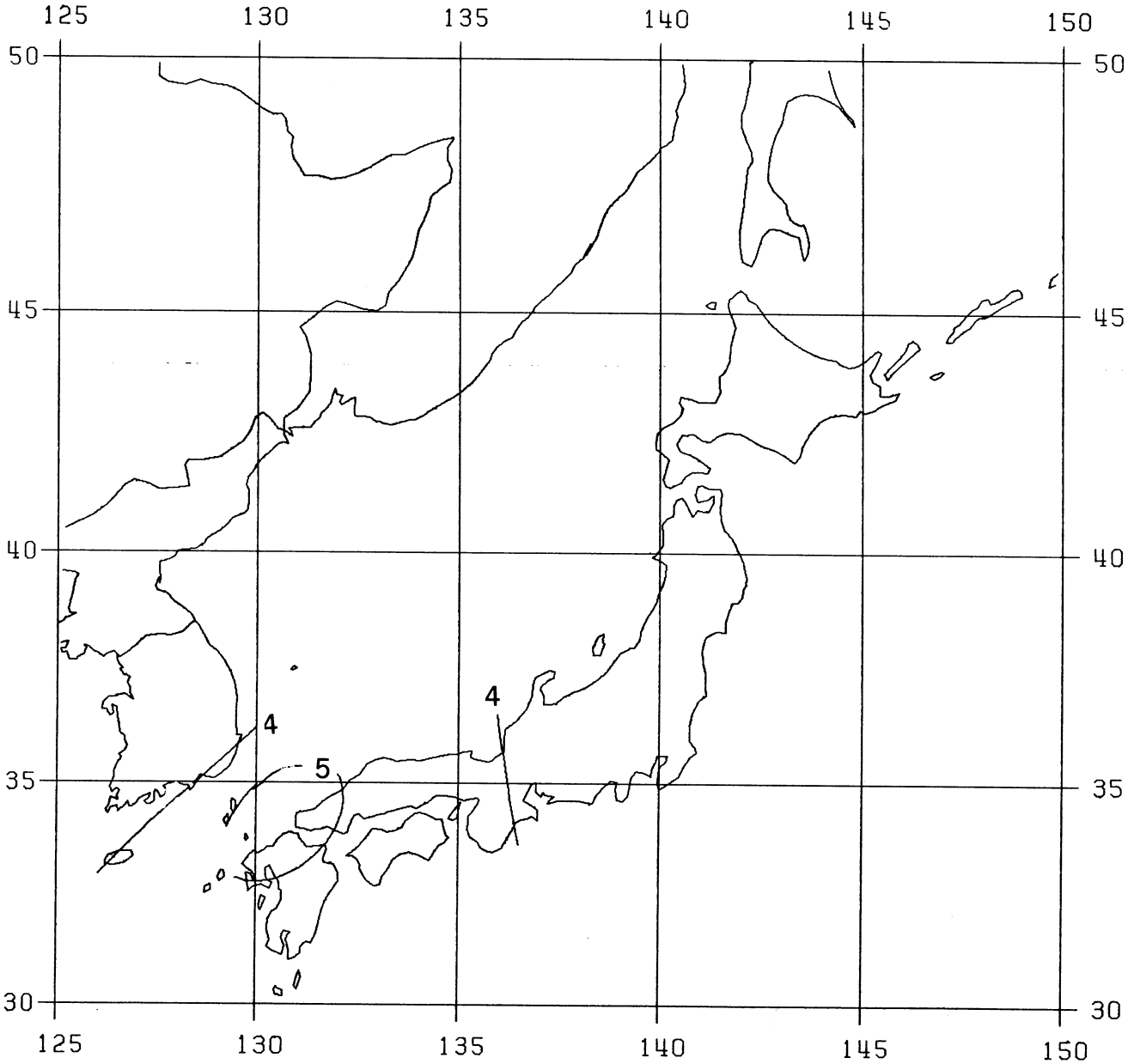

Figure 27.39. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (TD Area), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 1 Meter)

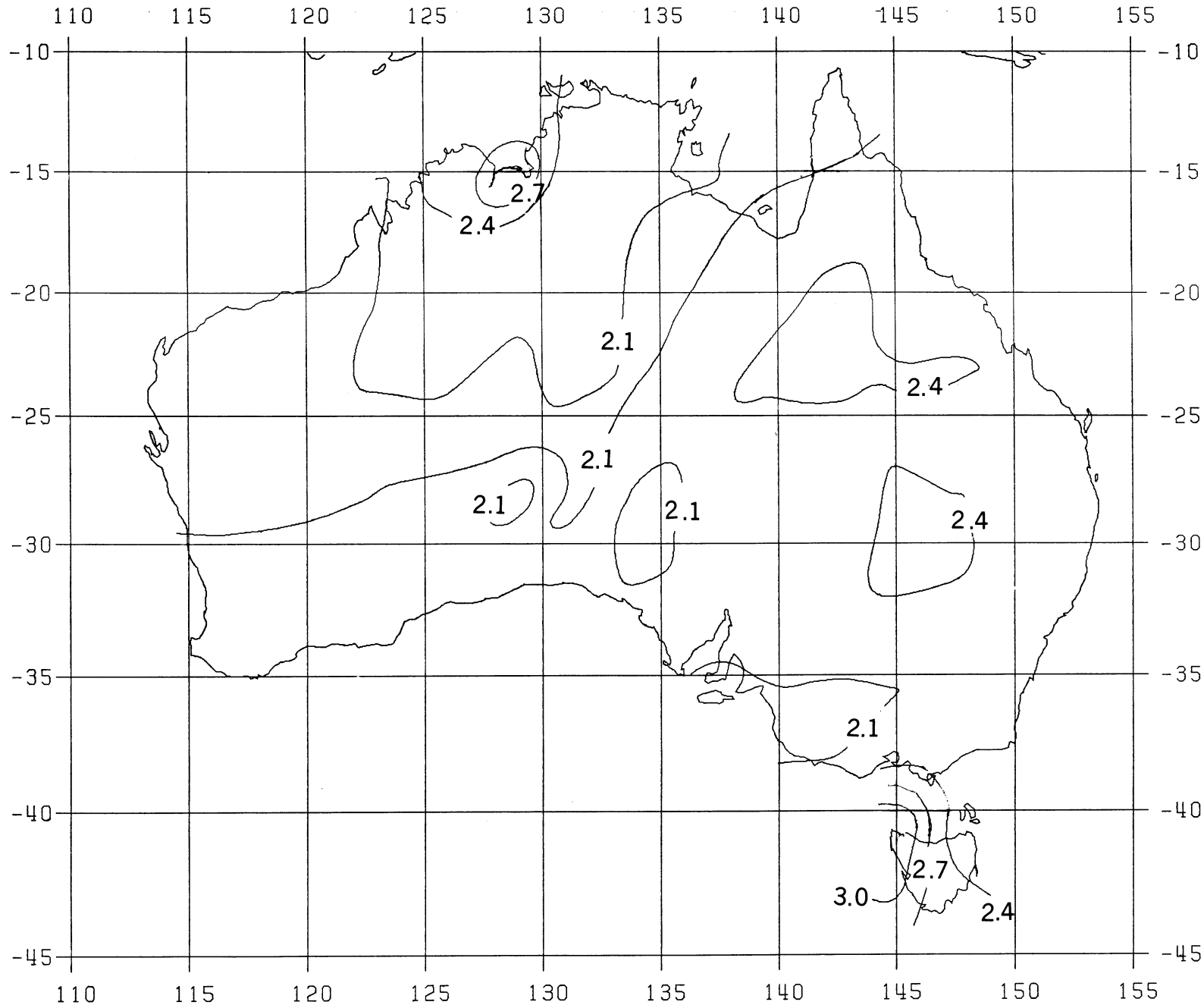

Figure 27.40. Accuracy (1σ) of WGS 84 Geodetic Latitudes at Doppler Sites (AGD 84 Area), Latitude Determined Using Datum Transformation MREs (Contour Interval = 0.3 Meter)

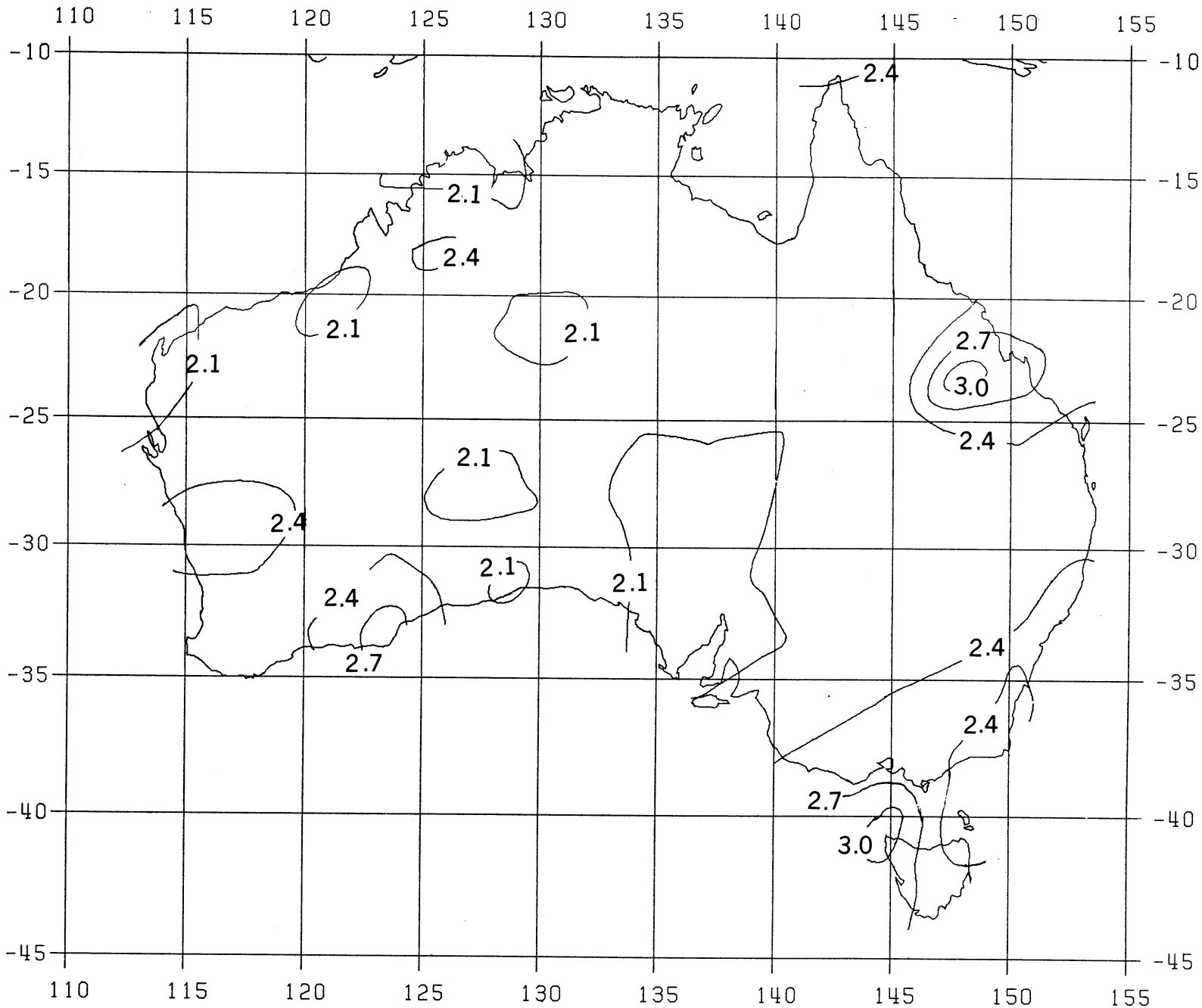

Figure 27.41. Accuracy (1σ) of WGS 84 Geodetic Longitudes at Doppler Sites (AGD 84 Area), Longitude Determined Using Datum Transformation MREs (Contour Interval = 0.3 Meter)

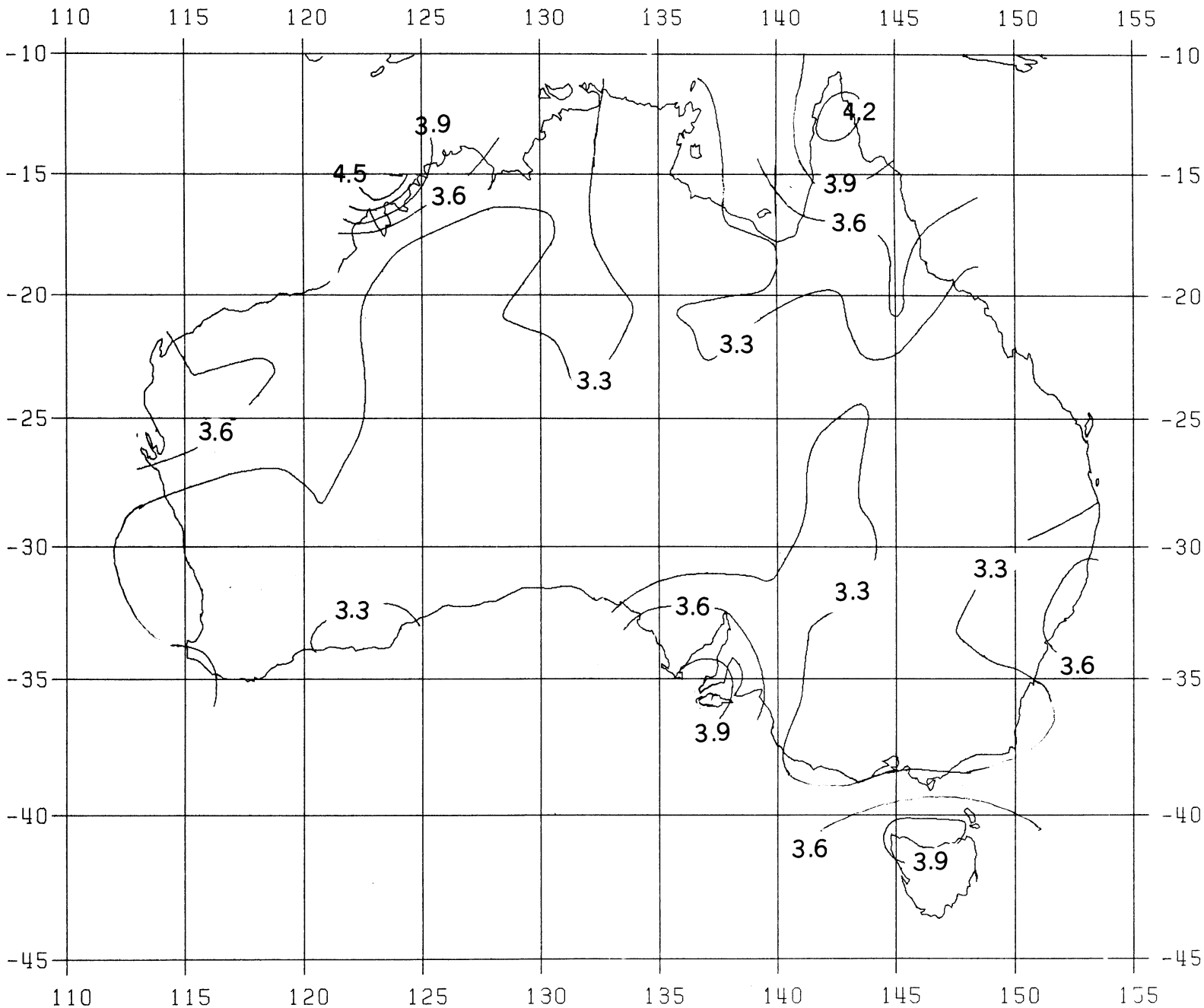

Figure 27.42. Accuracy (1σ) of WGS 84 Geodetic Heights at Doppler Sites (AGD 84 Area), Geodetic Height Determined Using Datum Transformation MREs (Contour Interval = 0.3 Meter)

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SECTION 28

ERROR CONVERSION FACTORS

Table 28.1

Error Conversion Factors* [5]

Notation				
Error Form	**Standard Error (One Sigma)**	**Probable Error**	**Map Accuracy Standard**	**Near Certainty Error**
Linear	σ (68.27%)	PE (50%)	MAS (90%)	3σ (99.73%)
Circular	σ_c (39.35%)	CEP (50%)	CMAS (90%)	$3.5\sigma_c$ (99.78%)
Spherical	σ_s (19.9%)	SEP (50%)	**SAS (90%)	$4\sigma_s$ (99.89%)

**SAS = Spherical Accuracy Standard

Linear Error

From \ To	50%	68.27%	90%	99.73%
50%	1.0000	1.4826	2.4387	4.4475
68.27	0.6745	1.0000	1.6449	3.0000
90	0.4101	0.6080	1.0000	1.8239
99.73	0.2248	0.3333	0.5483	1.0000

Circular Error

From \ To	39.35%	50%	90%	99.78%
39.35%	1.0000	1.1774	2.1460	3.5000
50	0.8493	1.0000	1.8227	2.9726
90	0.4660	0.5486	1.0000	1.6309
99.78	0.2857	0.3364	0.6131	1.0000

Spherical Error

From \ To	19.9%	50%	90%	99.89%
19.9%	1.000	1.538	2.500	4.000
50	0.650	1.000	1.625	2.600
90	0.400	0.615	1.000	1.600
99.89	0.250	0.385	0.625	1.000

*Errors are assumed to be random and uncorrelated.

SECTION 29

REFERENCES

REFERENCES

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SECTION 30

ACRONYMS

AGD 66	= Australian Geodetic Datum 1966
AGD 84	= Australian Geodetic Datum 1984
BIH	= Bureau International de l'Heure
BTS	= BIH Terrestrial System
CEP	= Celestial Ephemeris Pole
CEP	= Circular Error Probable
CIS	= Conventional Inertial System
CMAS	= Circular Map Accuracy Standard
CONUS	= Contiguous United States
CTP	= Conventional Terrestrial Pole
CTS	= Conventional Terrestrial System
DMA	= Defense Mapping Agency
DMAAC	= Defense Mapping Agency Aerospace Center
DMAHTC	= Defense Mapping Agency Hydrographic/Topographic Center
DMASC	= Defense Mapping Agency Systems Center
DoD	= Department of Defense
ECEF	= Earth-Centered, Earth-Fixed
ECI	= Earth-Centered Inertial
ECM	= Earth's Center of Mass
ED 50	= European Datum 1950
ED 79	= European Datum 1979
EGM	= Earth Gravitational Model
FRG	= Federal Republic of Germany
GRS 80	= Geodetic Reference System 1980
ITS	= Instantaneous Terrestrial System
MAS	= Map Accuracy Standard
MC&G	= Mapping, Charting, and Geodetic
MREs	= Multiple Regression Equations
NAD 27	= North American Datum 1927
NAD 83	= North American Datum 1983
NNSS	= Navy Navigation Satellite System

ACRONYMS (Cont'd)

NSWC	= Naval Surface Warfare Center (formerly Naval Surface Weapons Center)
OSGB 36	= Ordnance Survey of Great Britain 1936
OSGB SN 80	= Ordnance Survey of Great Britain Scientific Network 1980
PE	= Probable Error
PSAD 56	= Provisional South American Datum 1956
RMS	= Root-Mean-Square
SAD 69	= South American Datum 1969
SAS	= Spherical Accuracy Standard
SEP	= Spherical Error Probable
TD	= Tokyo Datum
TR	= Technical Report
UK	= United Kingdom
US	= United States
USNO	= United States Naval Observatory
WGS	= World Geodetic System
WGS 72	= World Geodetic System 1972
WGS 84	= World Geodetic System 1984