

# CHAPTER 12

## MAP COMPILATION AND CONSTRUCTION



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# INTRODUCTION

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The central operations of cadastral cartography are:

- A. Planning
  - 1. Cartographic design
  - 2. Generalization<sup>1</sup>
  - 3. Development of specifications and graphic standards.
- B. Map Compilation
  - 1. Compilation of reference data
  - 2. Analytical Bridging
- C. Map Construction
  - 1. Plotting control points and lines
  - 2. Cartographic drafting
- D. Map Finalization
  - 1. Map Detailing
  - 2. Final drawing (or tracing)
  - 3. Map editing
  - 4. Map reproduction
- E. Map Maintenance
  - 1. Upgrade map geometry to coincide with current land surveys.
  - 2. Update map lines, points and data to conform to new deeds, ordinances, subdivisions, etc.
  - 3. Upgrade photogrammetric detail to conform to new aerial photogrammetry.
  - 4. Remap when necessary.

This chapter will describe the map compilation and map construction operations. The explanation and description of the operations and suboperations are brief. In fact they will appear over-simplified. This is because *most* of the operations are performed using concepts and principles of the preceding chapters. It would be redundant to repeat that information here. For example analytical bridging is accomplished by using the trigonometric procedures for computing missing measurements, traverse closure, etc., that are defined in Chapter 9.

It is IMPORTANT, at this point, that we place special emphasis on two fundamental principles of cartography.

Principle 1. *The purpose for which a map system is designed governs the procedures, methods, and standards employed in that system.*

It is, therefore, incorrect to assume that one set of concepts, methods, and procedures will apply to every kind of mapping program. For example, a

photogrammetric map base is adequate for many kinds of mapping. This does *not* mean that it is adequate for *every* kind of map base. Likewise, the fact that the cadastral map system employs the cadastral land survey to control map geometry does not mean that this approach is applicable to every kind of map system.

Principle 2. *Maps are like fingerprints—no two are exactly the same. Consequently, the problems of each map will differ; thus requiring different approaches to problem solving.*

Therefore, it is impossible to provide one outline and one set of solutions that will apply to every mapping situation. All that we can provide is a *general* outline that applies to *most* situations. The solutions to the problems are accomplished by the precise scientific methods defined in the preceding chapters., and a *high degree of professional skill*.

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## DEFINITIONS

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*Analytical Bridging.* The assembly, evaluation, mathematical analysis. selection and rejection of all horizontal surveys. The purpose is to build a continuous network of survey quadrilaterals to *bridge* as many cadastral map elements as possible.

*Base Control Map.* A graphic-geometric network of *primary survey* quadrilaterals that serve as a base: for *secondary surveys*, for the lines and points to be plotted from instruments of conveyance and for the natural and cultural features to be supplied by aerial photography. Generally synonymous with *basic map control, control map base or control*.

*Map Life.* The *effective* life of any map. In cadastral cartography it is that period of time when a map accurately represents the latest surveys, aerial photos and deeds. It is measured from the time that the original map is completed to that point in time when it will no longer accommodate new property segregations, new surveys, new photogrammetric detail or new parcel numbers. It also terminates when map specifications and graphic standards are no longer adhered to. It is based on the principle that *the permanent map does not exist*.

*Map Triangulation.* A system of joined or overlapping triangles in which the size of angles and length of sides are either established from existing surveys, or are computed using existing survey data.

*Maverick Survey.* A survey that is not in harmony with abutting surveys. The term does not mean

that the survey is in error. In fact, new surveys are often labeled as maverick surveys because they are executed at a greater degree of precision than were the abutting surveys; hence, the measurements of the older surveys do not conform to the later.

*Primary Survey.* A survey that provides controlling data for bridging the section and township corners and the points, monuments and lines of other primary surveys, e.g., a subdivision survey, or a survey of a B.P.A. transmission line. See *secondary survey*.

*Secondary Survey.* A survey that does not provide measurements that could be used in map control. A survey that is subordinate to — or based on — a larger survey. A good example would be a survey of a lot in a subdivision, the subdivision survey would be the *primary survey*; the survey of the lot would be a *secondary survey*.

The eight *Generations of Control*. The author's classification of the various levels (or stages) of control now employed, or that were at one time employed in the cadastral map system. Generations one through six are in order of the quality of control; beginning with the lowest quality. This order of classification generally parallels the chronological order of employment in the cadastral map system; the sixth generation being the level of control now employed by the Department of Revenue. Levels seven and eight are considered superior approaches to map control to those now employed.

*Trilateration.* A method of surveying in which the lengths of the sides of triangles are measured.

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## DEVELOPMENT OF MAP CONTROL

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*What type of map control will provide us with the best framework upon which a cadastral map can be developed?* Since the inception of the cadastral map program a considerable amount of thought, time and money has been invested in developing map control. The Department of Revenue and the counties have tried various systems of control. These are listed below. Most of the early approaches to control failed to solve such problems as gaps, overlaps, loss of meridian, accumulative error, mismatching at map borders, etc. Once a scientific approach was employed at the sixth generation of control, most of the traditional cadastral map problems were eliminated.

The original sixth generation of control has been improved many times to keep abreast of technological changes; improvements made to take advantage of the positive elements of other control systems; and improvements made to correct some inherent weaknesses of the original plan. Therefore, it is reasonable to expect further developments; at least as long as there are problems to be solved.

*First Generation Control.* This level was employed in the early years of cadastral mapping. Under this system any desired point, line, or series of lines were employed as the foundation of the map; regardless of the weighted evidence that *other* points and lines would provide better control. Each map was drawn with no consideration to abutting data. Often, the U.S. Public Land Survey was employed at the control base; all other cadastral data was adjusted to fit the section lines. Some maps were constructed by plotting one deed, and then building onto that deed polygon by plotting abutting deeds, and so on. *Surveys were rarely used.*

*Second Generation Control.* This was a slight improvement. The U.S. Public Land Survey became the base, then section corners and section subdivision corners were adjusted to conform to some of the cadastral surveys.

*Third Generation Control.* This level of control was based entirely on U.S.G.S. horizontal control without regard for the cadastral surveys executed by the governmental and private survey agencies.

*Fourth Generation Control.* This could be considered as a *scientific approach*. It is like sixth generation control, except that it is based on a *random* selection of horizontal survey data.

*Fifth Generation Control.* Control at this level is generated from aerial photos or orthophotos (or both) employing good horizontal and vertical ground control. This level is excellent for many map purposes because, in a geographic sense, the spacial relationships of cultural and natural physical features are very accurate. However, when related to cadastral needs it falls short of supplying the monuments corners, measurements, and lines upon which the deeds are based.

*Sixth Generation Control.* This level requires the use of *all* available horizontal survey data to establish map geometry. It employs the analytical bridging techniques, fifth generation control (when available), and the State Plane Coordinate System. Moreover, it has been refined to include computer-assisted mapping applications. Under this sys-

tem, control is generated over wide areas, and is plotted on 8' x 3' sheets of polyester film. The system is as applicable to one section map as it is to control of many sections.

*Seventh Generation Control.* Generations five and six are employed here. This level of control would include full vertical control as well as full horizontal control of *all* major cadastral elements. It is superior to the preceding levels because at this level any uncontrolled points would be located by field survey.

*Eighth Generation Control.* This level would incorporate fifth and sixth generation control procedures. In addition, the State Plane Coordinate grid, U.T.M and geodetic coordinates would be applied. It would employ full use of the *National Horizontal Control Network* with a positional accuracy specification not exceeding 1 part in 100,000 (or 1:100,000). *Note: At present much of the NHCN is used in the sixth generation of control.*

This categorization is not to imply that any of the above methods of control are the *ultimate*. It is almost certain that control procedures will improve as photogrammetric and land survey techniques improve. Moreover, computer-assisted-mapping (CAM) is destined to change much of our outlook on the control problem.

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## MAP COMPILATION

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The first step in map compilation is the acquisition of *all* horizontal survey information. The word "all" is meant to be *all encompassing*. In other words, every U.S., state, county, city, and private survey (obtainable) must be considered in establishing cadastral map control. All other reference material should be obtained at this time (i.e., aerial photography, harbor charts, triangulation diagrams, quadrangle maps, etc.). The residual benefit of such a broad range of cadastral reference material is that you are building a reliable reference library for geographic names, contours, elevations, hydrographic features, vegetation features, cultural detail, physical features, demography, etc.

### Reference Sources

Many federal, state, county, and city agencies are engaged in surveying and mapping. A large percentage of the material produced by these agencies has *usable* reference material for cadastral maps, e.g., maps, charts, survey notes and data, aerial

photogrammetry, geodetic control data, and map data in digital form. The chart of figure 12-1 shows the reference sources for major cadastral elements and cadastral detail. The following list of agencies and addresses includes a brief description of their surveying and cartographic activities.

U.S. Forest Service USFS  
P.O. Box 3623  
Portland, OR 97208  
Ph. Maps 221-3765; Orthophoto 221-2927

*Maps of national forests, wilderness areas, planimetric 15' quads, primary series 7.5' quads, aerials photo of national forests.*

U.S. Corp of Engineers USCE  
P.O. Box 2946  
Portland, OR 97208  
Ph. 221-6473

*Maps of dams, reservoirs, navigable waterways, flood plain study areas. Various aerial photos 1936 to present.*

Bonneville Power Administration BPA  
P.O. Box 3621  
ETLK  
Portland, OR 97208  
Ph. 234-3361 ext. 4643

*Transmission line maps (containing excellent survey control data & coordinate data). Low altitude photography along trans. lines.*

Bureau of Land Management BLM  
(729 N.E. Oregon)  
P.O. Box 2965  
Portland, OR 97208  
Ph. 231-6273

*U.S. survey notes & plats (GLO & BLM). State of Oregon maps showing contours, county bdrys., highways, surface mineral and management status. Photo. of BLM lands; photomaps of Medford Dist; Orthophotos of Eugene Dist.*

Soil Conservation Service SCS  
Federal Building  
1220 S.W. 3rd Ave., (16 floor)  
Portland, OR 97204  
Ph. 221-2794

*Soil-type maps and reports. Aerial photo. of agricultural lands.*

Oregon State Forestry Dept. OSFD  
2608 State Street  
Salem, OR 97310  
Ph. 378-2504

*Maps of forest protection units, transportation, land manage. units, township aerial photo maps. High and low altitude photography.*

Geology & Mineral Industries                      OGMI  
1069 State Office Bldg.  
Portland, OR 97201  
Ph. 229-5580

*USGS maps; topo, geologic, mineral resource maps. Geologic hazards maps. Geothermal, geophysical, rock resource, oil and gas deposit maps.*

Land Conservation & Development                      LCDC  
1175 Court Street NE  
Salem, OR 97310  
Ph. 378-4926

*Maps of Oregon Coast (estuaries, forests, beaches, and dunes) and Pacific NW land resources inventory (land use, land ownership, energy, watersheds, soils).*

Division of State Lands                                      DSL  
1445 State Street  
Salem, OR 97310  
Ph. 378-3805

*Maps and data on submerged and submersible lands; navigable status of Oregonlr waterways, etc.*

Oregon Department of Transportation                      ODOT  
Map Distribution, Rm. 17  
Transportation Building  
Salem, OR 97310  
Ph. 378-6255 or 378-6256

*Right-of-way maps. Highway & road index maps. City maps. Aerial photos.*

Water Resources Dept.                                      WRD  
555 13th Street NE  
Salem, OR 97310  
Ph. 378-3671 or 378-8453

*Maps of Drainage basins, water rights, adjudication, watersheds, flood plains, thematic. USGS for sale.*

Cartography Center    PSU  
Portland State University  
Cramer Hall  
Portland, OR 97207  
Ph. 229-3916

*Cartographic facilities; map-related service, instruction, and assistance.*

Department of Geography                                      PSU  
Portland State University  
Cramer Hall  
Portland, OR 97207  
Ph. 229-3916

*Collection of State, Federal, private and local agency maps. Aerial photos.*

Environmental Remote Sensing                      ERSAL  
and Applications Lab.  
Oregon State University  
Corvallis, OR 97331  
Ph. 754-3056

*Aerial photo.; remote sensed data. Landstate MSS &RBY imagery. Skylab imagery. NASA high altitude (U2) aerials photo; lack & white & color infrared.*

Map Room - Kerr Library                                      OSU  
Oregon State University  
Corvallis, OR 97331  
Ph. 754-2971

*Maps from federal, state, private, and local agencies. SCS & ASCS photography.*

Cartographic Service    OSU  
Dept. of Geography  
Oregon State Umversity  
Corvallis, OR 97331  
Ph. 754-3141

*Cartographic facilities, services & assist.*

Map Room    UO  
University of Oregon  
165 Condon Hall (basement)  
Eugene, OR 97401  
Ph. 686-3051

*Large collection of maps & aerialphotos. Aerial photo archives (200,000 on file)*

Oregon Department of Revenue                      DOR  
Assessment & Appraisal Div.  
Urban-Rural Mapping Unit  
Revenue Building  
955 Center Street NE  
Salem, OR 97310  
Ph. 378-3381; Mgr. at ext. 8-8218

*Cadastral maps. Taxing district boundary information. Cadastral map standards Timber-type maps (not maintained). Some aerial photography Digital map file on part of Coos and Douglas County. Various historical maps. U.S.G.S. quad file, 15', 7.5' advanced and final (for ref. only). Microfilm--deeds, some co. survoeys, BLM survoeys (all), and old assessment rolls. Some 1/2" = 1 mile county maps. Legal file on various real property problems, i.e. ownership, submerged & submersible lands, assessment, roads, easements, etc.*

National Cartographic Information Ctr                      NCICW  
Western Mapping Center

U.S. Geological Survey 345 Middlefield Road Menlo Park, CA 94025 Ph. 415-323-8111 ext. 2427		Division of Cadastral Survey Bureau of Land Management (420) Washington, D.C. 20240 Ph. 202-343-8205	BLM/DCS
<i>Maintains information base on the location and availability of cartographic data. Sells copies of land use and land cover maps, maps of political units, hydrologic units, census county subdivisions, federal land ownership.</i>		Bureau of Mines Mine Map Repository Denver Federal Center Denver, CO 80225 Ph. 303-234-4181	BM
National Cartographic Information Center NCIC U.S. Geological Survey MS 507 National Center Reston, VA 22092 Ph. 703-860-6045		Bureau of Reclamation General Services Division Chief, Publications & Photo Branch 7442 Interior Building 18th & C Streets, NW Washington, D.C. 20240 Ph. 202-343-4683	BR
<i>National information service to make cartographic data easily accessible, i.e. maps, charts, aerial imagery, space imagery, geodetic control, digital data, cartographic publications, etc.</i>		Bureau of Census Users Services Staff Data Users Services Division Washington, D.C. 20233 Ph. 301-763-2400 or Geography Division, BC (same address)	BC
National Geodetic Survey Info. Center NOS National Ocean Survey National Oceanic & Atmospheric Admin. Rockville, MD 20852 Ph. 301-443-8631		Department of State Office of Geographer Bureau of Intelligence & Research 8744 State Department Bldg. 2201 C Street, NW Washington, D.C. 20520 Ph. 202-632-1428	USDS
<i>National network of horizontal and vertical control available (write.- Attn. National Geodetic Info. C18). Technical publications (Attn. Physical Science Services C513). Map Library (Attn. Map Library C513). Doppler geodetic surveys (C18), tide information (C3), aerial photos C3415). Coast mapping (C34).</i>		Division of Realty Fish & Wildlife Service 555 Matomic Bldg. 1717 H Street, NW Washington, D.C. 20240 Ph. 202-343-4676	FWS
U.S. Dept. of Agriculture USDA Aerial Photo. Field Office Geometrics Service Center PO Box 30010 Salt Lake City, UT 84107		U.S. Forest Service Publications Office Office of Information Washington, D.C. Ph. 202-447-3957 (for aerial photos try)	USFS/PO
<i>Provides aerial photo and satellite imagery. Geometrics service in support of National Forest management activities.</i>		U.S. Forest Service P.O. Box 2417 Washington, D.C. 20013 Ph. 703-235-8638	USF
User Service EROS EROS Data Center U.S.G.S. Sioux Falls, SD 57198 Ph. 605-594-6511	EROS	Office of Communications National Park Service 3043 Interior Bldg.	NPS
<i>Provides access to imagery from landstat, skylab, U.S.G.S. aerial photography, NASA aircraft data, remote sensing products, and training.</i>			
Bureau of Indian Affairs BIA Public Information Office 18th and C Street NW Washington, D.C. 20245 Ph. 202-343-7435	BIA		

18th and C Streets, NW  
 Washington, D.C. 20240  
 Ph. 202-343-6843

Soil Conservation Service  
 Education & Publication Branch  
 Information Division  
 U.S. Department of Agriculture  
 Washington, D.C. 20250  
 Ph. 202-447-5063

Government Printing Office  
 Assistant Public Printer  
 (Superintendent of Documents)  
 U.S. Government Printing Office  
 N. Capitol and H Streets, NW  
 Washington, D.C. 20402  
 Ph. 202-275-3345

Library of Congress  
 Geography and Map Division  
 845 S. Picket St.  
 Alexandria, VA 22304  
 Ph. 202-370-1335

National Archives & Record Section  
 Cartographic Archives Div.  
 Archives Bldg.  
 Pennsylvania, Ave. at 18th NW  
 Washington, D.C. 20408  
 Ph. 202-523-3062

*Maps, charts, technical data, aerial photography associated with specific agency responsibilities.*

Pacific Marine Center  
 NO Survey  
 NOAA  
 1801 Fairview Ave., E.  
 Seattle, WA 98102  
 Ph. 202-442-7657

*Nautical Chart Sales (includes of estuaries) and geodetic data.*

Real Estate Division  
 Oregon Dept. of Commerce  
 Commerce Bldg.  
 158 12th St. NE  
 Salem, OR 97310.  
 Ph. 378-8422

*Info. on subdiv. control and on condominiums.*

NCIC/Oregon Station

SCS/EPB

GPO

NA

NOS/NOAA

ORED

Oregon State University  
 Marine Science Center  
 Newport, OR 97365  
 Ph. 867-3011

*Info. for coastal management-scientific and tech. data. Some maps.*

Secretary of State  
 136 State Capitol  
 Salem, OR 97310  
 Ph. 378-4139

*Info. on annexations*

Secretary of State  
 Archives Division  
 1005 Broadway NE  
 Salem, OR 97310

*Historical maps. Microfilm of deeds and other county records.*

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## PRODUCT & INFORMATION SOURCES

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The following guide will assist you in locating cartographic, photogrammetric, and technical information. ORS means the data is contained in the Oregon Revised Statutes; CA = county assessor's office; CC = county clerk; CS = county surveyor; CE = county engineer; CRD = county road department; RR = railroad company; PS = private surveyors; TC = title company. The other acronyms are listed with the preceding agency addresses.

INFORMATION OR PRODUCT	PRODUCE AGENCY	OBTAIN OR REFER.
Aerial photography	Most U.S. agencies	OSFD
(some)	OSFD	OGMI
(county-wide)		DOR
		CA
		DSL
	DOT	DOT
(over 200,000 on file)		OSU
		UO
(some)		EROS
		SS/AD

INFORMATION OR PRODUCT	PRODUCE AGENCY	OBTAIN OR REFER.	INFORMATION OR PRODUCT	PRODUCE AGENCY	OBTAIN OR REFER.
Aeronautical charts	NOS	NOS	County roads		CS
Beach vegetation line	DOT	DOT			DOT
		ORS			CRD
(some)		DOR			CE
(on cadastral maps)		CA	(on cadastral maps)		CA
Boundaries, taxing dist.		CA	(some data)		DOR
		CC	Donation land claims	BLM	BLM
		DOR	(microfilm)		DOR
		DOT	(survey field notes		CC
		SS	or)		CS
(cities of 2500 or more)	BC	GPO	(on cadastral maps)		CA
Boundaries, property		(Deeds)	(good survey ties)		BPA
		PS	(survey ties)		PS
(All on cadastral maps & records)		CA	(survey ties)		RR
		CS	Deeds		CC
(some on r/w maps)		BPA	(some on microfilm)		DOR
(some on r/w maps)		DOT	(on microfilm)		SS/AD
(submerged & submersible lands)		DSL	Digital map file	DOR	DOR
Boundaries, state		ORS		Lane Co.	CA
Boundaries, county		ORS		Marion Co.	CA
		CS	Estuary data	DSL	DSL
		DOT	(some)		DOR
Boundaries, state parks	DOT	DOT	Federal lands	BLM	BLM
Boundaries, nat'l parks	NPS	NPS		NASA	NASA
Cadastral maps	DOR	DOR	(Forests)	USFS	USFS
	DOR	CA	(National parks)	NPS	NPS
	CA	CA	(State map of BLM lands)	BLM	BLM
		TC	(U.S. map of BLM lands)	BLM	BLM
Census data	BC	BC	Flood plain maps	WRD	WRD
		SS		NOS	NOS
City maps		LCDC		SCS	SCS
	DOT	DOT		USCE	USCE
(some(historical))		DOR	Forest maps (U.S.)	USGS	USGS
		Planning Commissions	(state)	USFS	USFS
City streets	cities		Geodetic control	OSFD	OSFD
		CS	data	BLiML	BLiM
(ded. on subdiv.)		CC		CS	CS
		DOT	(Horiz. & vert. net)	USCE	USCE
Channels (nav. waters)	USCE	USCE	(some)	USGS	USGS
		DSL	Geologic maps	NOS	NOS
Contours	USGS	USGS		NOS	DOR
	NOAA	NOAA		USGS	USGS
	NOS	NOS		OGMI	OGMI
					UO
					OSU

INFORMATION OR PRODUCT	PRODUCE AGENCY	OBTAIN OR REFER.	INFORMATION OR PRODUCT	PRODUCE AGENCY	OBTAIN OR REFER.
Geographic names	USGS	USGS	Railroads	RR	RR
(streams)	WRD	WRD	(good file)	RR	DOR
(highways and rds)	DOT	DOT	(some)		CS
(cities)	Oreg. Bluebook		(intersect R/W)	BPA	BPA
	NOS	NOS	(intersect R/W)	DOT	DOT
Geographic maps	NOS	NOS	Reservoirs	USCE	USCE
(land use)	USGS	USGS	(general)	WRD_	WRD
Harbor lines	USCE	USCE	Riparian rights	DSL	DSL
	USCE	DSL	(some data)		DOR
(some data)	USCE	DOR	Soils	SCS	SCS
Highways (state)	DOT	DOT		CA	CA
	FHWA	FHWA	Subdivisions		CA
(some)		CE	(official file)	PS	CC
(some)		CS	(ref.)		ORED
	ODT	DOR	(survey info.)		CS
(on Indian lands)	BIA	BIA	(present ownership)	CA	CA
(on federal lands)	FHWA	FHWA	(approval)		CS
(map/U.S. system)	FHWA. _	GPO	(approval)		CA
Hydrographic	NOS	NOS	Topographic maps	USGS	USGS
	USCE	USCE		OSFD	OSFD
	USGS	USGS		NASA	NASA
(beach erosion)	USCE	USCE		WED	WRD
(tidal data)	NOS	NOS	(some)		DOR
Indian reservations			Transmission line		
(land surveys)	BIA	BIA	surveys	BPA	BPA
Land use	USGS	USGS	(some)	BPA	DOR
	SCS	SCS	(on cadastral maps)		CA
	ERSAL	ERSAL	Triangulation data	USCE	USCE
				NOS	NOS
(& planning commissions)		LCDC		USGS	USGS
				NOS	DOR
Mines	BM	BM		NOS	CS
(surveys)	BLM	BLM		DOT	DOT
(microfilm)	BLM	DOR		BPA	BPA
(surveys)		PS		PS	PS
(surveys)	PS	CS	Taxing dist. boundaries		DOR
(deeds)		CC			CA
Meander lines	ELM	BLM			CC
	BLM	DOR			DOT
		DSL	Township & section		SS
		CS	lines	BLM	BLM
Nautical charts	NOS	NOS		USGS	USGS
	USCE	USCE	(R/W maps)	BPA	BPA
Ownership data	(deeds)	CC		PS	PS
		CA	(microfilm)	BLM	DOR
		CS	(or GLO)	BLM	CS
(state hwy.)	DOT	DOT	Water rights	WRD	WRD
(submersible/ submerged)	DSL	DSL			
(along R(Ws))	BPA	BPA			
(RR)	RR	RR			

## Analyzation of Data

After the surveys have been obtained they should be reviewed to determine which are *primary surveys* and which are *secondary surveys*. The surveys and their controlling elements should be indexed on a grid of the area to be mapped. For example, assume that the area we are mapping is of sections 1, 2, 11, and 12. The survey index (figure 12-2) need be nothing more than a sketch of the section lines, boundaries of surveys, corners located by survey and coordinates, subdivision names, county survey numbers, etc. The *secondary surveys* are noted and circled.

The rough index provides a plan for bridging the major components of this area. It also shows where information is missing. Figure 12-2 illustrates the importance of considering all surrounding surveys when developing control. For example, if our objective were to draw only section 12, it should be obvious that it would be a mistake to ignore the surveys of the abutting sections. Therefore, our compilation of surveys must extend beyond the boundaries of the area being mapped.

The next step is to compare the surveys to determine which are in harmony and which are maverick surveys. Once this is done the maverick surveys should be analyzed to see *why* each survey does not agree with abutting survey data. There

are several possibilities here. These are outlined in Chapter 6 (Surveys and Surveying).

It is possible that the survey traverse merely needs to be balanced. Or, possibly the surveyor's deflection angles and distances agree with the abutting surveys; only the bearings are different. In such cases it is possible that the surveyor has failed to convert the magnetic azimuth to true azimuth; or possibly it is only his base meridian that is in error. The main point to remember is do not *ignore the survey just because it fails to agree with abutting information*. Moreover, do not ignore *all* of the information of a survey just because part of the survey is found to be in error.

## Explanation—Horizontal Control Elements. Analytical Bridging

In the surveying and mapping of large areas the exact curvature of the sea level surface of the earth must be taken into consideration. For this reason, the basic surveys of the U.S. are called *geodetic surveys*. There is an intricate net of precise geodetic surveys over the U.S. It comprises the equivalent of about a dozen east-west arcs of triangulation and about thirty north-south arcs, although they are by no means in a regular pattern, as this statement infers. The aim has been to have the main arcs spaced at regular intervals over the country and to have intermediate areas well covered with

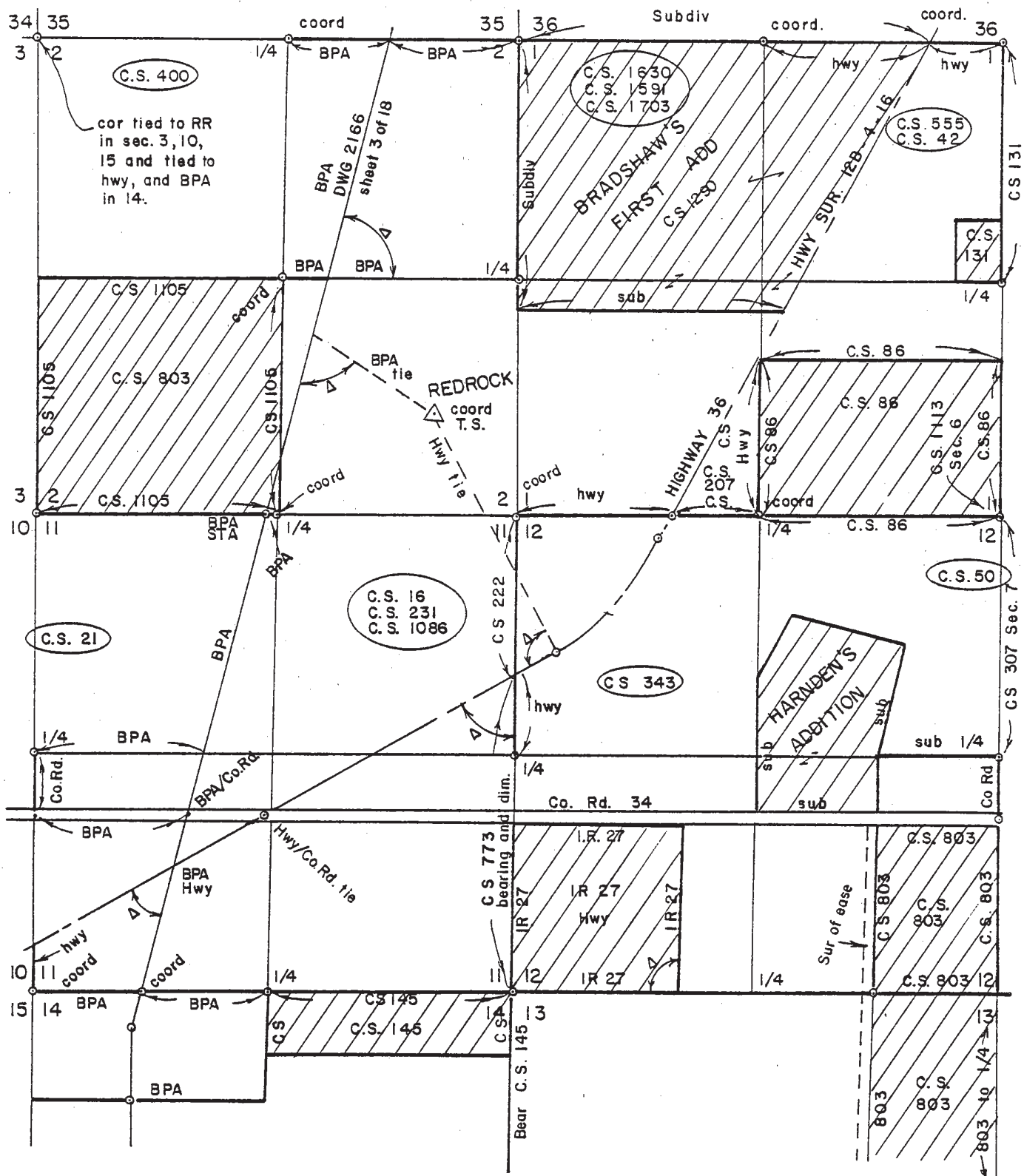


Figure 12-2

INDEX OF SURVEYS

supplementary. arcs, and area triangulation. This precisely determined network serves as a basis for intermediate and local surveys and for all kinds of geodetic cartography.

Latitudes and longitudes have thus been determined for many thousands of marked stations scattered over the U.S. Surveys of small areas may be based on any of these marked points at any time with the assurance that they may be correctly coordinated in position with all precise surveys and maps of the entire country and with all local surveys so connected. The permanency of the results of surveys thus connected to the national net is also assured since any marked points that become lost or that lose their integrity may be duplicated by new surveys based on nearby stations.<sup>2</sup>

Figure 12-3 is a section of the “Yaquina Head to Columbia River” U.S.C. and G.S. (NOAA) triangulation chart. It serves to illustrate the tight map control that can be maintained through use of such information. Triangulation is a very efficient method for making surveys over extensive areas. It avoids the tedious, time-consuming, expensive operation of measuring the lengths of all lines that enter into a survey. It consists of a system of connected triangles with all angles carefully observed but with only an occasional length actually measured on the ground. Each measured length is known as a base. By use of these measured bases and angles, the lengths of all other sides can be computed by trigonometry (as explained in chapter 9 on *Map Computations*). If the latitude and longitude are known together with the azimuth to one of the other stations, the latitudes and longitudes of all other points and the azimuths of all other lines may also be derived. Moreover, the computed sides of such a network would provide ties from every station to all other stations; hence, in figure 12-3, lines could be drawn between all triangulation stations to produce a very extensive network of lines representing known distances (measured and computed).

Triangulation is a simple method when used over small areas where the earth’s curvature need not be considered, e.g., that illustrated in figure 12-3. It is further simplified by introduction of state plane-coordinate systems. In connecting the coordinated stations, surveyors and cartographers can ignore the geodetic factors of the area being controlled and consider only the plane coordinates, computing surveys on the simple cartesian coordinate system. Thus surveys will be coordinated with the national net as if the more complex geo-

detic coordinates were used. Yet, latitudes and longitudes can be derived with little difficulty should the need arise.

Figure 12-4 is an example of horizontal control data available from the U.S. Department of Commerce (NOAA). The data includes latitude and longitude, plane coordinates of the stations, a detailed description of the location of each triangulation station, and the lengths and azimuths of the lines between contiguous stations. This information is also on file in the Oregon Department of Revenue. One important caution should be observed. *Be careful not to confuse the geodetic azimuths of directions of the lines with the state plane coordinate directions.* The two kinds of azimuths may differ considerably since the convergence of the meridians is considered in deriving the geodetic azimuths; but the plane-coordinate, or coordinate grid, azimuths are strictly *rectangular* with reference to the central meridian (see Chapter 7).

Now that you understand the triangulation network concept, you can visualize a map triangulation net composed of the known points and measurements of the surveys you have assembled. Moreover, from these known points, angles, and measurements, it will be possible to compute the missing sides of many triangles. For example, from the surveys indexed in figure 12-2 a network of lines, angles, and triangles can be derived as shown in figure 12-5. From this data many other missing triangle sides can be computed. The network, in this case, is enhanced by the BPA and OSHD highway tie to the *Redrock* triangulation station.

The triangulation station, the BPA survey and the highway survey provide ties to the Oregon State plane coordinate system. This provides the data needed to compute the x-y coordinates of the other points of our network. Plotting these points will be a simple exercise of measuring the x and y distances from the coordinate grid points.

The application of triangulation procedures to develop cadastral map control is known as *analytical bridging*. It simply means “to analyze all available survey data, to establish the needed control data, and perform the necessary mathematics to establish needed angles and distances, for bridging certain points and parts of a map area.”

To obtain tight mathematical control over your geometric network, the lengths of the common sides of each triangle must agree with the sides of abutting triangles. Therefore, it is advisable to perform a side check for each side of each triangle critical



OREGON VOL III PAGE 716  
 QUAD 441231 STATION 1009  
 OREG. LATITUDE 44 30' TO 45 00'  
 LONGITUDE 123 00' TO 123 30'  
 DIAGRAM NL 10-11 SALEM

# HORIZONTAL CONTROL DATA

by the  
 Coast and Geodetic Survey  
 NORTH AMERICAN 1927 DATUM

NOV 1969  
 U.S. DEPARTMENT OF COMMERCE  
 ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION  
 COAST AND GEODETIC SURVEY

## ADJUSTED HORIZONTAL CONTROL DATA

NAME OF STATION COR 9 USE  
 STATE OREGON YEAR 1969 SECOND ORDER  
 LOCALITY WILLAMETTE RIVER CORVALLIS OREGON  
 SOURCE G-14384 FIELD SKETCH OREG 142

GEODETIC LATITUDE 44 32 59.74401	ELEVATION 210	METERS 64.0
GEODETIC LONGITUDE 123 14 35.07242		FEET 210
STATE COORDINATES (FtM)		
STATE & ZONE	CODE	PLANE ADJUSTMENT
OREG. N.	3601	326 17 54
	1,285,029.37	334,150.63
		- 1 56 43

\* PLANE ADJUSTMENT HAS BEEN COMPLETED BY THE U.S. GEOLOGICAL SURVEY

TO STATION ON OBJECT	GEODETIC AZIMUTH (From 1927)	PLANE AZIMUTH*	CODE
COR 7 USE	324 21 10.7	326 17 54	3601

NOTE: ELEVATION DETERMINED BY URECA INC

QUAD NO. 44 1231 /

## DESCRIPTION OF TRIANGULATION STATION

NAME OF STATION: COR-9 (U.S.E.) STATE: Oregon COUNTY: Benton  
 CHIEF OF PARTY: L. F. Smith YEAR: 1969 DESCRIBED BY: W. E. Gloepfll

OBJECT	BEARING	DISTANCE		DIRECTION
		FEET	METERS	
COR-7 (U.S.E.)		00 00	00.0	
COR-8 (U.S.E.)		138 38	28.6	

HEIGHT OF TELESCOPE ABOVE STATION MARK 1.6 METERS; HEIGHT OF LIGHT ABOVE STATION MARK METERS  
 SURFACE STATION MARK DISTANCE FROM CENTER OF INSTRUMENT TO CENTER OF LIGHT ABOVE STATION MARK METERS  
 UNDESIRABLE STATION MARK SUBJECTS WHICH CAN BE SEEN FROM THE GROUND AT THE STATION

The station is 4.4 miles southeast of the city of Corvallis on the east bank of the Willamette River.

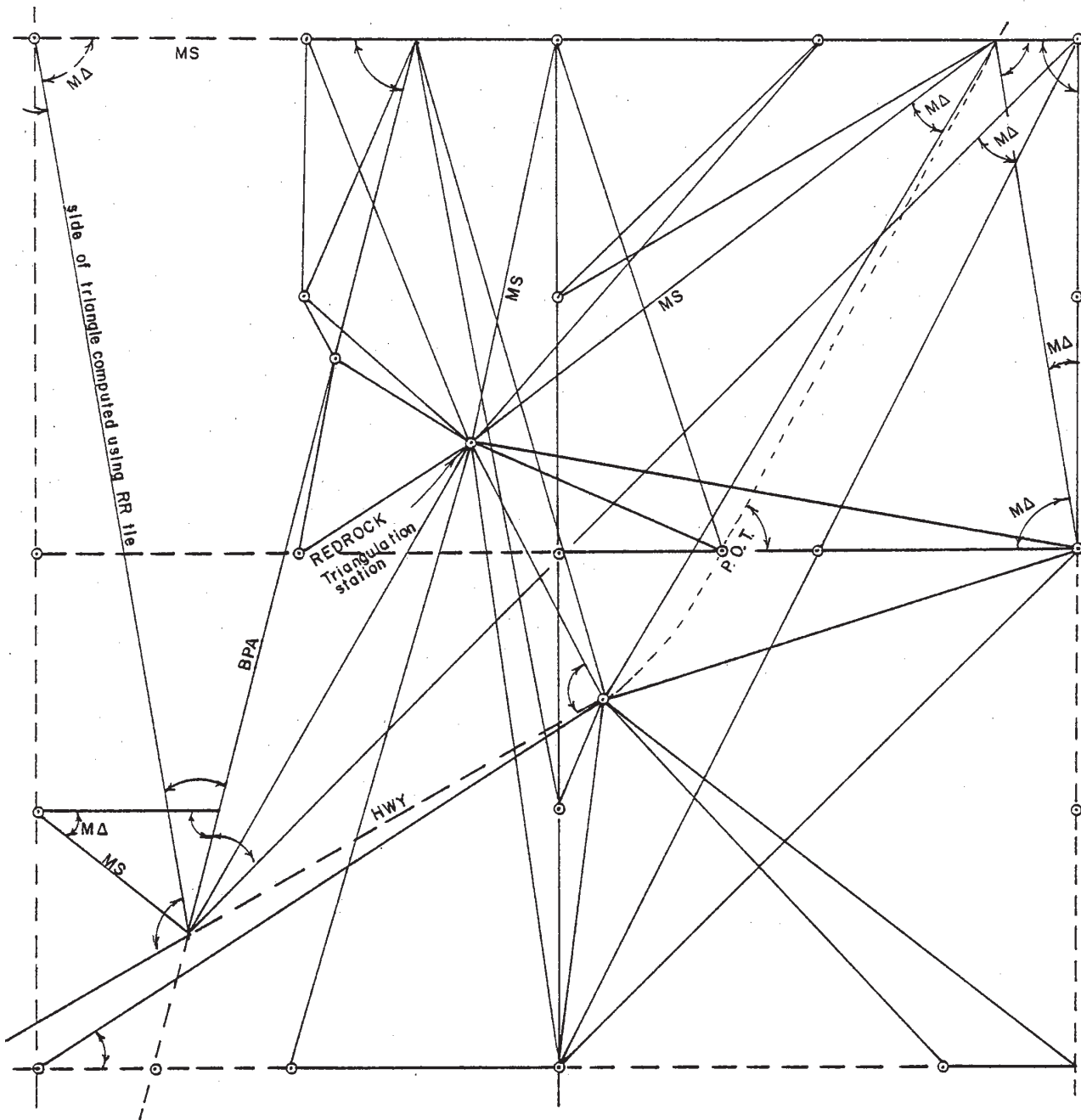
To reach the station from the Corvallis Post Office, proceed north on S.W. 2nd Street for 0.3 mile to N.W. Van Buren Street (U.S. Highway 34); turn right and go east on U.S. Highway 34 for 1.15 miles to the Peoria Junction; turn right and go southeast on Peoria Boulevard for 1.0 mile to a side road right (County Road G121); turn right and go southwest on County Road G121 for 1.0 mile to a side road right which is the entrance to Brown's farm; turn right and go west for 0.2 mile on gravel road to wood line; turn right and proceed north on track road along east side of river on top of high bank for 0.7 mile. Turn left and go west from track road for approximately 230 feet to river bank and station.

The station mark, stamped "COR-9 1966", is a U.S. Engineers bronze cap on a 2 1/2 inch iron pipe set in concrete. It is 50 feet east of the river on top of a rock revetment, and 2 feet west of a witness post.

There were no reference marks established for this station.

✓ CHE

\* Refer to notes in manual of triangulation and other publications of triangulation. † Direction-angle measured clockwise, referred to initial station. ‡ To screen marks only, when no trigonometric leveling is being used. USCGM-DC 27171-P89



MS = Missing side of triangle that can be computed

MΔ = Missing angle that can be computed

 Known Δ

MAP TRIANGULATION NETWORK OF AREA OF FIGURE 12-2

Figure 12-5

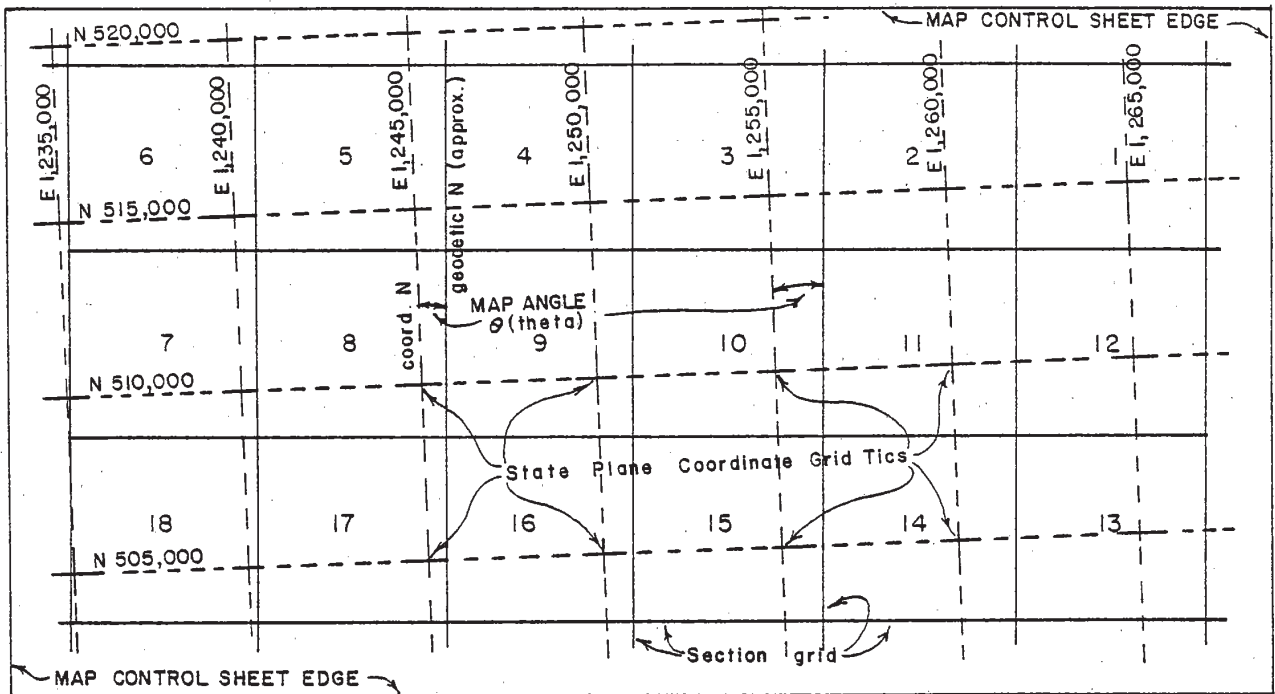


Illustration of State plane coordinate grid correctly positioned on the map control sheet to accommodate the township - section grid.

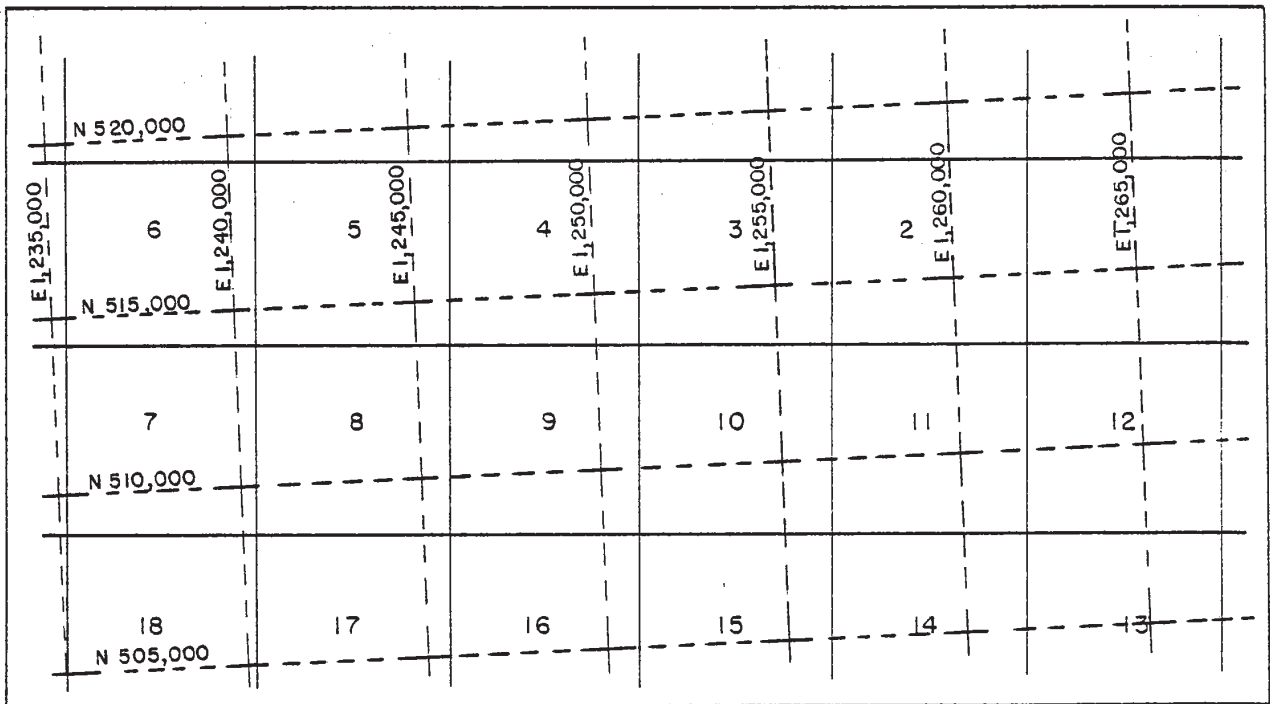


Illustration of State plane coordinate grid incorrectly positioned on the map control sheet. Result is that the township centerline lies off the control sheet.

Figure 12-6

to control. All side equations should be prepared either in a clockwise or counterclockwise order. When the signs are predominantly plus or minus, the error is sufficient to warrant further analysis of the survey data and recalculation. Serious errors warrant a field check by trilateration.<sup>3</sup>

The trigonometric computations of missing measurements are relatively simple; however, maverick surveys will complicate the task of establishing the reliability of available data, thus requiring a considerable amount of data manipulation. Certain triangle and quadrilateral sides must be considered as a reliable base for your network. For example, bench mark ties of BPA transmission line easements have proven extremely reliable for establishing an accurate base for map triangulation. (A word of caution. Although certain governmental surveys, such as those executed by BPA, have a reputation for being reliable, they are *not* infallible. Therefore, be willing to accept the fact that, on occasion, errors will be found in surveys executed by even the greatest of survey teams.)

Remember, to ensure adequate control of the area to be mapped, map triangulation *must* extend to points outside that area.

*Where survey data is not available to compute the sides of certain needed triangles (or for that matter — quadrilaterals), the deeds should be reviewed to see if they can supply the necessary measurements.*

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## MAP CONSTRUCTION

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### Map Scale

Before plotting map control at  $1'' = 200'$  scale and  $1'' = 100'$  scale a pilot control map should be developed at a scale of  $1'' = 400'$ . All horizontal control should be plotted at this scale. This method allows you to check control over a wide area, and provides assurance that all abutting and adjacent control data has been analyzed and used. Even though your final map covers only  $\frac{1}{4}$  of a section, the development of control over a section, several sections, over even one-half township (as is the practice in the Department of Revenue Mapping Unit) should not be considered as a wasted effort. The development of control over the **broader area can be used when it becomes necessary** to construct the abutting  $\frac{1}{4}$  section maps.

### Plotting The Coordinate Grid

Before you can begin plotting the x and y coordinate points established by analytical bridging, it is necessary to draft the coordinate grid on your control sheet. We recommend a cartesian grid of 1,000 feet for  $1'' = 100'$  scale and  $1'' = 200'$  scale maps, and a grid of 5,000 for  $1'' = 400'$  scale and  $1'' = 2000'$  scale maps. The grid tics should be rounded to the thousand foot x, y position, e.g. N 505,000, E 1,250,000 (rather than N 505,200, E 1,250,900.28); see figure 12-6.

The edges of the control map must be oriented to the approximate geodetic cardinal bearings. Hence, they will generally run parallel to the township - section grid. This means that the coordinate grid will be on an angle to the edges of the map. That angle is commonly known as the *mapping angle* (or *map angle*). It is equal to theta ( $\theta$ ) the angle correction. The mapping angle will differ slightly for each map (see Chapter 7). It can be obtained from the horizontal control data sheet (example in figure 12-4). Figure 12-6 illustrates the difference between the coordinate grid and the township section grid (rectangular survey grid).

Figure 12-6 also serves to point out one common error made in positioning a coordinate grid on a control sheet. As the bottom illustration shows, if the coordinate grid is not correctly located on the sheet, part of the needed township -section grid will lie off the map. The top illustration shows the same coordinate grid positioned so as to accommodate the needed township-section lines.

The location of the grid lines can be planned by using the State plane coordinate grid of the USGS quadrangle maps to determine how that grid lies in relation to the township-section line grid. *When using the quadrangle map as a reference for the Oregon State plane coordinate grid, take care to not mistake the UTM or geodetic grid points for State plane coordinate grid points. The UTM grid is marked off in grads set at 1000 meters; the geodetic coordinates are marked off in degrees, minutes and seconds. The Oregon State plane coordinate grid is labeled in feet at one point on each map boundary, the other grid points being unmarked.* See figure 12-7.

### Plotting The Control Points

All control points should be converted to the N, E state plane coordinate values (or the x and y values) so that they may be plotted from the coordinate grid you have constructed on the control sheet.

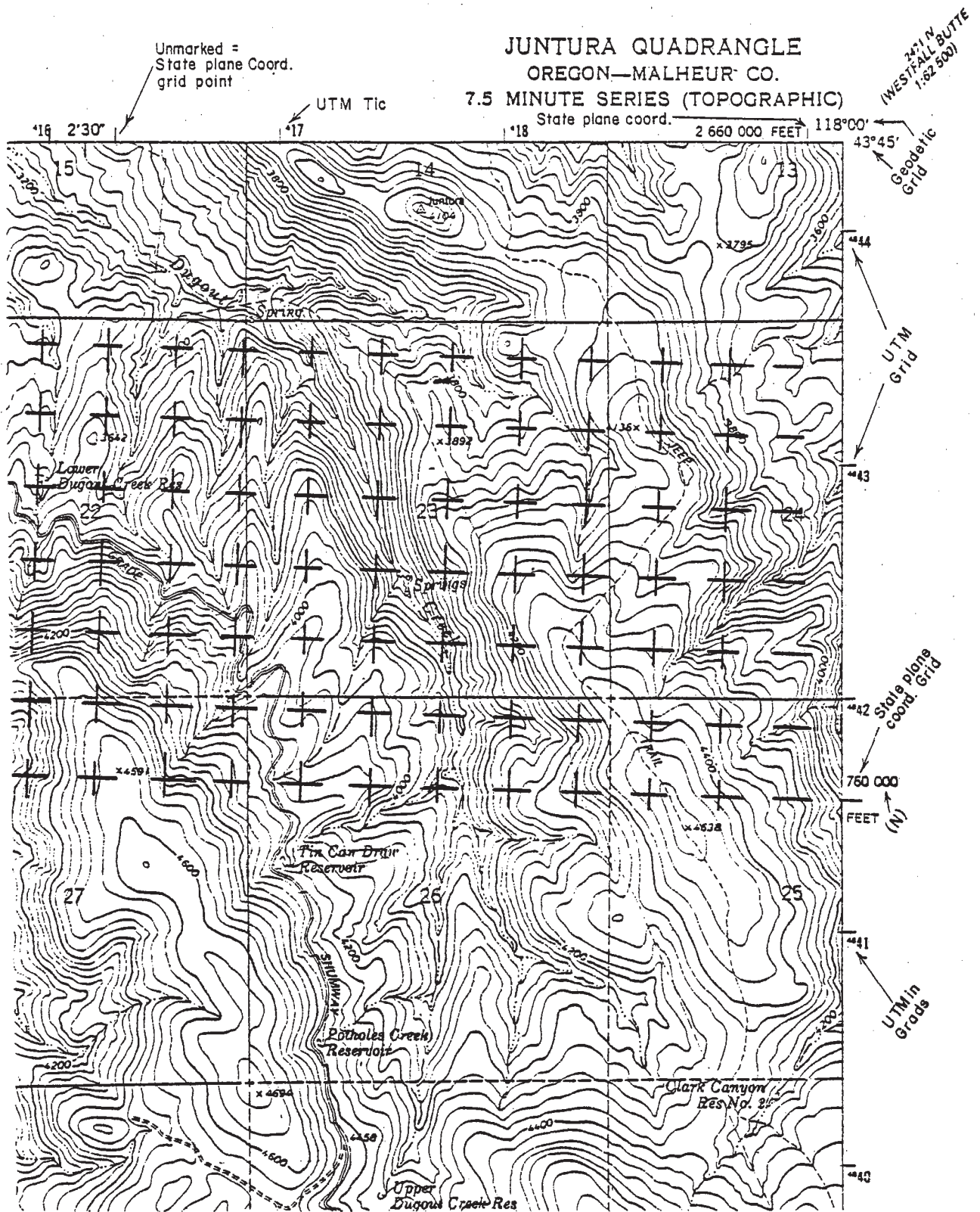


Figure 12-7

U.S.G.S. quadrangle used for determining location of State plane coordinate grid, and for determining approximate map angle (theta, or  $\theta$ , the correction angle).

All plotting should begin with what you consider as the most reliable primary survey data. Plot only by measuring the x and y distances from the coordinate tics. Do not plot by bearing and dimension at this time. Plotting should follow this order:

1. Locate coordinated section corners. (This will ascertain that all of the township-section grid will be contained on the control sheet.)
2. Locate the stations of the national control net.
3. Plot the transmission line points and important ties to 1/4 comers, 1/16 corners, Donation Land Claim corners, subdivision corners, railroads, road intersections, etc.
4. Plot the traverse of the state highways and secondary highways; locating important ties, intersections, etc. Also plot the surveys of roadside parks and stockpile sites.
5. Plot the traverse of railroads; including side-tracks and station site survey data.
6. Plot county road centerlines (beginning with the latest road surveyed).
7. Plot any major pipeline or ditch traverses and ties to important points.
8. Plot subdivision points and lines; beginning with the largest and most recent subdivisions.
9. Plot the governmental (federal, state, county and city) and private surveys; beginning with the largest and most recent.

As plotting progresses, the traverse lines should be added to connect the plotted points. After the lines are added the bearings and point to point dimensions should be measured to check the accuracy of the x and y plotting of points. When survey data conflicts with surrounding data, the conflict must be noted on the control map.

The next step is to check the geometry of your control map. Orthophotos, aerial photos and reliable topographic and planimetric maps can be used to check the spacial relationships of the map.

## Completing Map Control

At this stage of the map construction operation it is essential to complete the section line grid; including meander lines of rivers and lakes, (see chapter 10), Donation Land Claim corners and lines, and patented mining claims. When all survey and reliable reference data is exhausted, use the DLC-BLM, surveys.

Be sure to identify found corners and coordinated corners. Note all corner offsets and discrepancies. Add survey and survey drawing numbers. All en-

gineering stations of right-of-ways should be located and labeled.

Next, note the centerpoint location of secondary surveys. This is done by using a red pencil to print the survey number in the approximate location on the control map.

Completion of the control map involves using photogrammetric methods to plot unsurveyed rivers, creeks, lakes, ponds, ditches, major logging roads and other major roads. Use a blue pencil for riparian lines and a red pencil for road lines. *Be certain to read Chapter 10 before plotting riparian boundaries.*

Finally, where several map areas are included on one control map. use a yellow pencil to outline the final map boundaries of each cadastral map. Chapter 2 provides the rules for determining map boundaries.

*The control map should always be retained and maintained for future control problems. Therefore, it is essential that you not add unnecessary detail to that base. For example:*

1. Subordinate right-of-way data of highways, county roads and railroads (such as curve data).
2. Interior subdivision data (such as lot, block and street lines, dimensions and numbers).
3. Secondary survey points, lines and dimensions.
4. Ownership data.
5. Deed boundaries, bearings and dimensions.
6. Tax lot numbers.
7. Code area lines and numbers.
8. Parcel acreages.

## Map Lift-off

Once the map control is completed, each map area is transferred to an 18" x 20" layout sheet. When tracing the control lines, be sure to center the map area in accordance with the graphic standards (Chapter 2). All map detailing will be completed on this lift-off (or layout sheet).

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# MAP FINALIZATION

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## Map Detailing

To complete the cadastral map it is now necessary to plot the supplemental lines, points and data of the right-of-ways, subdivisions and primary surveys.

Next, plot the secondary surveys. Although they may have little effect on the final outcome of the map, they

do represent *official* land ownership data; therefore, it is essential that they be recorded on the map. The inclusion of this information will simplify the plotting of the deeds because most secondary surveys represent existing or future parcels of real property. In effect, the survey is a *picture* of what the parcel polygon should look like, the deed description fails to accomplish this. Moreover, in most cases the survey controls the deed. This is in recognition of the fact that *the office of a deed description* is not to identify or locate *the land*, but to afford the *means* of identification. Most courts rely on intent and on *land surveys* to accurately locate the property boundary.<sup>4</sup> (Even if the secondary survey appears to not represent the lines of any parcel of real property, it should still be recorded on the cadastral map. It may represent the boundaries of only an *interest* in real property.)

At this point in the map finalization operation the deed boundaries should be plotted. In this step we are developing the inventory of real property. All real property must be accounted for. The process includes the discovery and location of real property, and the solving of deed ambiguities (that is - for assessment purposes - not legal purposes). *Note: a supplemental chapter will be supplied on deeds, boundary control, and legal principles.*

Before tax lotting and acreage computation it is advisable to add the tax code area lines and numbers to the map. Do not treat this process lightly. It is essential to locate the code lines *exactly* as they have been legally established, described, approved, and recorded, This must be done accurately to make certain that no taxpayer is being assessed in the incorrect taxing district. It is as essential to equity as is any other assessment function.

The final stages of map detailing involve acreage computation (see chapter 9) and tax lotting. Tax lotting is the process of assigning parcel numbers to the parcels of real property of each map. The specifications for tax lotting are discussed in chapter 2, and are described in chapter 3.

After the tax lotting is completed, edit the map to see that the information and graphics conform to the standards and specifications of the standard cadastral map system. This is often done after the tracing has been produced.

## Final Drawing

The last major step in the cadastral map is often executed incorrectly. This is the *Final drawing* or *the ink tracing*. On the one hand we find excellent cadastral cartography lost in a sloppy, inaccurate

tracing. On the other hand we have seen excellent tracings of extremely inaccurate maps; as if a *pretty picture* was all that counted. What we are seeking is a neat, well-executed tracing that accurately displays the points, lines and details of the cadastral map layout; and in accordance with the graphic standards defined in chapters 2 and 3.

Chapter 11 describes the drafting function of producing the final tracing. A supplementary chapter will be added to define tracing production by computer-assisted interactive plotters (CAMS - on Computer Assisted Mapping).

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## SPECIAL NOTES

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The system of map control outlined in this chapter will work for any cadastral map, regardless of the area covered or the map scale. Moreover, it is as applicable in the maintenance operation as it is in initial map construction.

When developing map control for areas abutting your first control map, use the State plane coordinate tics of the first control map as the grid base for your abutting map. This will provide some assurance that the maps will match at their borders.

Map control can be greatly enhanced by use of computer-assisted-mapping systems (CAMS). The fact that data entry into CAM systems relies on rectangular coordinates means that the State Standard Cadastral Map system is ideally suited for CAMS applications. For example, traverse data in bearings, and dimensions can be entered into the central process unit, converted to x and y coordinates, and automatically plotted at any scale by the computer driven plotter. Any data already in x and y form can be entered directly and automatically plotted. Another advantage of CAMS is that plots can be made at any scale regardless of the scale of the original resource. When map control is hand plotted, the plotting process must be repeated by hand for each scale. When control is done via CAMS, the work need only be hand plotted once; the plotter will automatically reproduce the original work at any scale (including metric scales).

*A supplemental chapter will be provided on CAMS concepts and application in cadastral cartography.*

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## Endnotes

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1. *Generalization* actually overlaps design. It is the thought process in determining graphic objectives, scales, standards of accuracy, i.e., preceding the writing of specifications and standards.
2. *Horizontal control data*. Special publication no. 227 (revised 1972); U.S. Department of Commerce, NOAA.
3. *Trilateration* is a method of surveying in which the lengths of the triangle's sides are measured.
4. See *Gubser v. Town*, 273 P.2d 430, 202 (Corpus Juris Secundum).