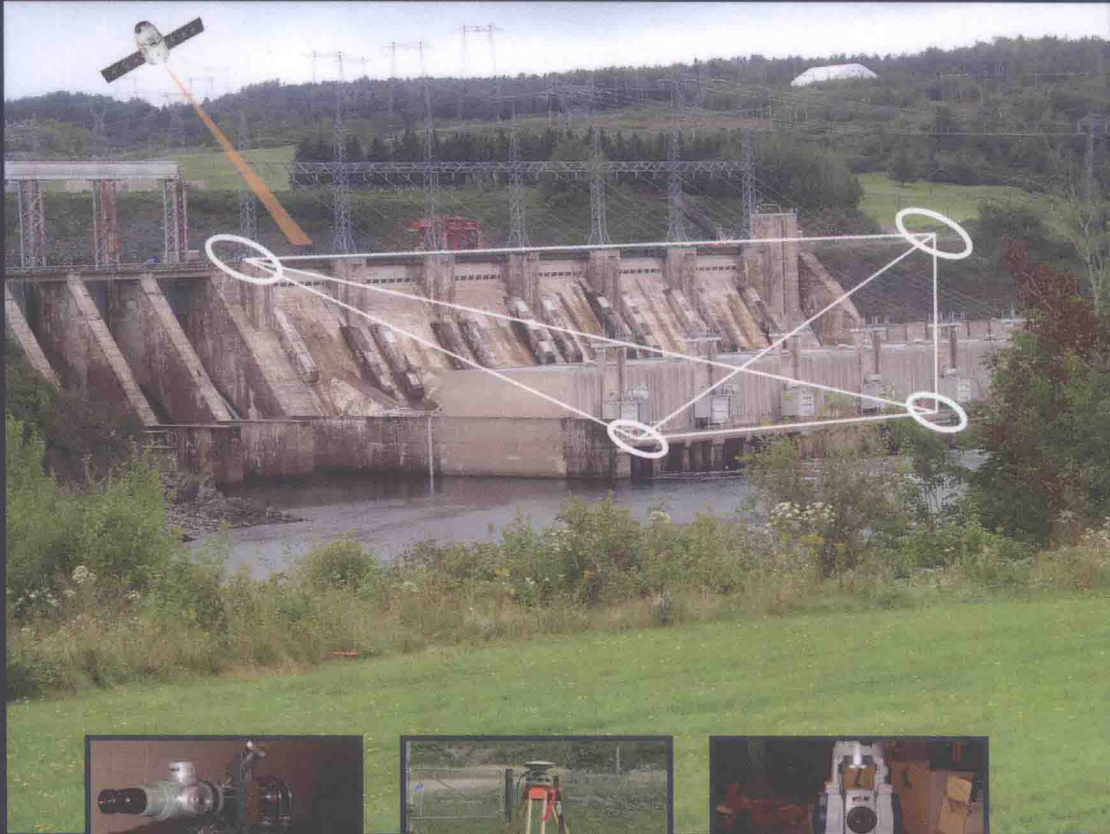


Precision Surveying: The Principles and Geomatics Practice



John Olusegun Ogundare, Ph.D.

WILEY

PRECISION SURVEYING

The Principles and Geomatics Practice

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WILEY

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Published by John Wiley & Sons, Inc., Hoboken, New Jersey
Published simultaneously in Canada

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Library of Congress Cataloging-in-Publication Data:

Ogundare, John Olusegun.

Precision surveying : the principles and geomatics practice / John Olusegun Ogundare, Ph.D., Instructor of Geomatics Engineering, Department of Geomatics Engineering Technology, School of Construction and the Environment, British Columbia Institute of Technology (BCIT)-Burmaby.

pages cm

Includes bibliographical references and index.

ISBN 978-1-119-10251-9 (hardback)

I. Surveying. I. Title.

TA545.O364 2015

526.9-dc23

2015021577

Typeset in 10pt/12pt TimesLTStd by SPi Global, Chennai, India

Printed in the United States of America

10 9 8 7 6 5 4 3 2

2 2016

ABOUT THE AUTHOR

John Olusegun Ogundare received his B.Sc. and M.Sc. degrees in surveying engineering from the University of Lagos, Nigeria, and M.Sc.E. and a Ph.D. in high precision and deformation analysis from the University of New Brunswick (UNB) in Canada. He has been in the field of geomatics for over 30 years, as a surveyor in various survey engineering establishments in Africa and Canada and also as a surveying instructor or teaching assistant in universities and polytechnic institutions in Africa and Canada.

For over 8 years, he has been serving as a special examiner for the Canadian Board of Examiners for Professional Surveyors (CBEPS) with the responsibility that includes setting and marking exams on the subject “Map Projections and Cartography” and then on the subject “Coordinate Systems and Map Projections.” As a subject-matter expert in those subjects, he has also had the opportunity to serve as a consultant to the Canadian Council of Land Surveyors (CCLS) in 2007 and 2009 in reviewing and making recommendations to a Joint Syllabus Development Task Force on the subject description, prerequisites, texts, and references and in developing learning outcomes and study guides for the two subjects. The material that he has developed on these subjects is currently being used in accrediting university programs and in granting equivalencies to technical schools for related courses and also in assisting the professional associations in evaluating the credentials of candidates for professional membership in surveying. He is also a representative on the CBEPS Board of Directors and the CBEPS Exemptions and Accreditation Committee. The CBEPS Board establishes, assesses, and certifies the academic qualifications of individuals who apply to become land surveyors or geomatics professionals or both, in Canada, while the CBEPS Exemptions and Accreditation Committee is responsible

for evaluating courses offered by post-secondary institutions in terms of their equivalence to individual CBEPS Syllabus items.

Dr. John Olusegun Ogundare has been working as an instructor of geomatics technology (in the diploma and degree programs) for about 20 years at the British Columbia Institute of Technology (BCIT), Canada, where he teaches subjects such as Advanced Topics in Precision surveys, Geodetic Positioning, Least Squares Adjustments, Mathematical Cartography. He also mentors the Bachelor of Technology students in their technical projects and reports. Some of his BCIT-funded works included providing manuals for CBEPS-accredited courses, which he developed and teaches to full-time and distance-learning students. Some of those funded courses are the Advanced Topics in Precision Surveys, Geodetic Positioning, Special Topics in Least Squares Adjustment, and Mathematical Cartography. Apart from being an instructor, Dr. John Olusegun Ogundare has also served for over 10 years as a member of the quality committee of the BCIT School of Construction and the Environment and for over 5 years as a member of the School Research committee. His current main professional interest and expertise include monitoring and analysis of deformations in engineering and geoscience projects; precision engineering surveys; geodetic control surveys, analysis and optimization; spatial data analysis and adjustments; coordinate systems and map projections; rock mechanics instrumentation, ground subsidence in mining areas and GPS applications.

FOREWORD

“Precision Surveying comes as a very needed textbook in North America. It fills the gap between existing textbooks dealing with basic principles of surveying and textbooks dealing with the theory of geodetic science. Theory of advanced surveying techniques, their proper use in engineering and geoscience projects and thorough accuracy analysis have been missing in the contemporary technical literature in geomatics. Dr. John Olusegun Ogundare, the author of the book, was one of my best graduate students at University of New Brunswick about 20 years ago. He was a hard working, young scientist, eager to learn, and very thorough in his work. This is reflected in this textbook, which brings enormous amount of information on modern surveying techniques of high precision, their proper use, and very detailed analysis and evaluation of surveying projects. Setting out and high-precision alignment of engineering structures, advanced techniques in mining and tunneling surveys, and structural and ground deformation monitoring and analysis are covered in this book with several case studies and practical examples. Readers at all levels of their knowledge in geomatics will certainly benefit from this textbook. My congratulations go to the author.

Adam Chrzanowski, Ph.D., Drh.c., P.Eng.
Director of Canadian Centre for Geodetic Engineering
University of New Brunswick

PREFACE

Precision surveying is not a specific area of discipline such as geodesy, hydrography, remote sensing, and photogrammetry. It is a geomatics engineering practice that applies any appropriate field of geomatics to projects in order to achieve a desired accuracy or precision; it deals with important aspects of real-world problems, such as designing and monitoring human-made infrastructures for millimeter-level movements, alignment of large machines in industrial environment, and so on. Some of the concepts and techniques involved have been developed over several decades, and some have just been accomplished recently. Although the basic concepts and techniques have not changed significantly and are not likely to change in the next several years, they are still not popular and are mainly understood by researchers or academic experts. This is partially due to the complex theoretical background involved, which are usually difficult for students and practicing surveyors/geomatics engineers to grasp.

My primary motivation to write this book came from my over 15 years of experience in teaching related courses to the Bachelor of Geomatics engineering technology students at the British Columbia Institute of Technology (BCIT) Canada, and my 8 years of being a special examiner for the Canadian Board of Examiners for Professional Surveyors (CBEPS) on Coordinate Systems, Map Projections, and Cartography subjects. My involvement in 2007 and 2009 as a consultant to the Canadian Council of Land Surveyors (CCLS)/CBEPS to develop learning outcomes, study guides, and reference materials for one of the subjects they use as entrance requirements toward becoming a Canadian professional surveyor also gave me an invaluable insight into a definite need for a comprehensive textbook on precision surveying. One of the most difficult tasks I have had is finding appropriate books on Precision (Advanced) Surveying to recommend to students; to the best of my knowledge,

no comprehensive and dedicated books are available for this subject. I also wrote this book as a framework for learning underlying principles and procedures of precision surveying with examples that are simple enough for the geomatics students and the practicing surveyors/engineers to understand and to help them develop their interest in precision surveying and the interdisciplinary aspects.

I had two main goals in writing this text: to satisfy the need for a comprehensive textbook on precision surveying that would deal with the totality of precision surveying principles and practice, including the recent developments in geodetic surveying and the interdisciplinary collaborations with other fields; and to demystify various aspects of precision surveying so that practicing surveyors/geomatics engineers can apply them to real-world problems. My initial effort toward realizing a comprehensive precision book was in developing a manual titled "Precision Surveying: The Principles and Practice," funded by BCIT, which I have been using in delivering my precision surveying courses to students at BCIT. This manual has evolved over a number of years with many updates based on suggestions and corrections from students, academic colleagues, and those from the industry. Recently, during my 1 year professional development leave to the Canadian Centre for Geodetic Engineering (CCGE) at the University of New Brunswick (UNB) in Canada, I updated the manual to include more undergraduate and graduate courses, such as Survey Design and Analysis (or Geomatics Network Design and Analysis), Precision Surveying, Engineering Surveying, Mining and Tunneling Surveying, and Industrial Metrology.

In comparison with other geomatics books, this book is considered unique because of its in-depth treatment of many specialized topics and modern trends in geomatics that have only been discussed, up till now, in articles, journals, and conference papers. Although the book places more emphasis on concepts and principles to prevent its contents from aging too quickly, some theoretical discussions and complex derivations of formulae are avoided when they are not relevant to the understanding of the concepts being presented. Moreover, this book does not include descriptions of measuring techniques and some basic instrumentation, which can be found in elementary surveying books.

This book consists of 14 chapters and 4 appendixes. Chapter 1 explains the main properties of precision surveys with regard to basic survey procedures and different traditional measurement techniques; it distinguishes the properties of the main classes of precision surveys, examines general terms in the precision geodetic survey techniques, and presents some safety issues and their management in relation to precision survey projects.

Chapter 2 discusses survey observables, measuring instruments, and the theory of observation errors, including the application of the concepts of confidence regions, the importance of equipment testing and calibration and the statistical analysis tools for survey measurements and parameters. In Chapter 3, an in-depth discussion is given on various standards and specifications available for geomatics projects, including their representations, interpretations, relationships with quality assurance/quality control measures, and their use in geomatics projects.

Accuracy analyses and evaluations of survey measurements and their measurement systems, including error sources and their treatment are presented in detail in

Chapters 4–6. Chapter 4 deals with angle measurement and the measurement systems; Chapter 5 describes electronic distance measurements and the measurement systems; and Chapter 6 analyses elevation difference and coordinate difference measurements and the relevant equipment, such as geodetic leveling and Global Navigation Satellite System (GNSS) equipment.

Chapter 7 discusses survey design and analysis, including the main purpose, the steps involved, the elements and problems of network design, and the issues related to deformation monitoring schemes. The description of commonly used three-dimensional coordinate reference systems, their needs, and the common models for three-dimensional coordinating systems are presented in Chapter 8. Also presented in this chapter are detailed explanation on the concepts, features, and accuracy limitations of some coordinating systems, such as electronic theodolite coordinating system, GNSS, airborne laser, and terrestrial laser scanning systems.

Comprehensive discussions on deformation monitoring techniques and analysis with regard to operating principles of relevant instruments, design elements of deformation monitoring schemes, data gathering, data processing, and data analyses, including comparisons of different techniques and their main advantages and limitations are given in Chapters 9–11. Chapter 9 discusses the traditional geodetic techniques; Chapter 10 covers modern high-definition surveying (HDS) and remote sensing techniques while Chapter 11 carefully evaluates geotechnical and structural techniques. Some of the discussions in Chapter 10 include the essential properties and features of HDS techniques, such as laser scanning, ground-based interferometric synthetic aperture radar (GBInSAR) and Light Detection And Ranging (LiDAR) systems; and the satellite-based InSAR. Chapter 11 identifies the differences between geotechnical and geodetic deformation monitoring schemes, analyses geotechnical deformation measurements, and explains the accuracy specifications for various geotechnical instrumentations with regard to deformation monitoring and how the geotechnical monitoring techniques complement geodetic monitoring techniques. This chapter is presented from the geomatics point of view so as to inform and acquaint the geomatics specialists with the relevance of geotechnical monitoring techniques to their practice.

Chapters 12 and 13 describe the main elements of mining and tunneling surveys. Chapter 12 starts with the definitions of some mining terminology, discusses the problems and various techniques of orientation transfer in mining and tunneling surveys, and evaluates the sources of systematic and random errors in alignment and underground surveys, including how the errors are minimized. In Chapter 13, the basic elements and methods of tunneling surveys are described. This includes a discussion on approximate effects of lateral atmospheric refraction on alignment surveys, horizontal and vertical design and simulation of tunneling surveys, error analysis of underground traverse surveys, and the determination of grid azimuth from gyro azimuth measurement for underground traverse surveys.

Chapter 14 gives a comprehensive description of the main techniques of precision alignment, such as direct laser alignment, conventional surveying techniques, optical tooling, laser interferometric techniques, and polar measurement techniques; the chapter also explains the main sources of error and the advantages and limitations

of the different techniques. The book ends with four appendices: Appendices I–III containing sample tables for use in statistical analyses of data, and Appendix IV presents some commonly used units.

Since this book is based on the manual that has already been used for several courses taught by the author at the undergraduate level, it can be considered to have been tested through teaching on the bachelor degree level. Certain features of the book are designed to aid in the learning and teaching activities: the chapter objectives, which provide an overview of the material contained in that chapter; and a number of example problems with suggested solutions, which are to assist readers in understanding the principles discussed. The use of this book, however, is recommended for third and fourth year technological and university undergraduate courses as well as for graduate courses. Some aspects of the book, however, can be adapted for use in second year courses if the topics of the courses are well organized with the method of least squares adjustment course taken concurrently. In general, a good understanding of elementary surveying, geodesy, and the method of least squares adjustment are recommended prerequisites to understanding some of the concepts discussed in this book.

Apart from being appropriate for use as textbook in college and university classes, this book is also a valuable tool for readers from a variety of surveying backgrounds, including practicing surveyors/engineers who are interested in precision surveys, geomatics researchers, software developers for geomatics, and so on.

John Olusegun Ogundare
Burnaby, B.C., Canada
9 July 2015

ACKNOWLEDGMENTS

The author would like to acknowledge and thank all of those bodies and individuals who have contributed in any way to the formation and updating of this book. The author is particularly indebted to British Columbia Institute of Technology (BCIT), Canada, for providing the funding for the development of the manual on which this book is based; without this funding, this book would not have been possible.

Special thanks are due to Dr. Adam Chrzanowski (Professor Emeritus, University of New Brunswick in Fredericton), the author's graduate study mentor and teacher, who provided the author with a vast material resource on various aspects of the studies resulting in this book, and for his constructive and valuable criticism. Dr. Chrzanowski is particularly acknowledged for his help in facilitating the author's professional development leave to the Canadian Centre for Geodetic Engineering (CCGE) at the University of New Brunswick in Canada, where the author wrote a substantial part of this book. In addition, a thank you to Dr. Anna Chrzanowski and Maciej Bazanowski of the CCGE for their invaluable support, friendship, and encouragement. The author also gratefully acknowledges the help received from the many papers, books, seminars, lecture notes, and reports, which were written by many other specialists in the area of precision surveys.

The author wishes to recognize the assistance of Mr. John Fletcher of the New Brunswick Power (NB Power) Generation, Mactaquac Generating Station, N.B., Canada, who devoted several hours of his time to taking the author round the Mactaquac dam monitoring systems and for providing source material on geotechnical instrumentations at the dam. The author is grateful to him and to the other NB Power staff for willingly responding to his various requests for information and for tirelessly answering the author's endless questions.

Other individuals/corporations who contributed to this book in one way or another are Dr. James Secord of the University of New Brunswick, who provided the author with valuable comments, suggestions, and reference materials; Mr. Brian Roulston and other staff members of the Potash Corporation, Sussex mine, N.B., who helped the author in understanding the workings of the underground mine; Dr. Tomas Beran and other staff members of Measurand Inc., Fredericton, N.B., Canada, who helped in clarifying the workings of a particular MEMS system and for reviewing the related section of this book; the staff of RST Instruments Ltd, Coquitlam, B.C., Canada, for providing the author with useful information on their geotechnical instrumentations; the Canadian Board of Examiners for Professional Surveyors (CBEPS) for giving the author the permission to reproduce some of their past Exam questions on Advanced Surveying subject in this book; and Alistair Boakes of BCIT Learning and Teaching Centre, who helped in the design of the cover page for this book. The author is grateful to all of them and also to the reviewers, who pointed out problems and identified some areas of improvement to this book.

Finally, the author is grateful to his wife, Eunice, and his children, Joy and Isaac, for their patience, understanding, and encouragement.

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