

Contents

Acknowledgment	3
Introduction	13
1. Basic Characteristics of the Basin	15
1.1 Location and Accessibility	15
1.2 Population, Settlements and Health Status	15
1.3 Land Cover	22
2. Selected Physical and Geographical Settings.....	27
2.1 Geomorphology.....	27
2.2 Soil and Vegetation Cover	29
2.3 Climatic Characteristics	31
2.3.1 Climatic Zones and Measurements	31
2.3.2 Precipitation	37
2.3.3 Evaluation of Other Climatic Characteristics.....	46
2.4 Hydrography and Hydrology of the Jemma River Basin	48
2.4.1 Surface Water Network Development	49
2.4.2 Surface Water Regime.....	50
2.4.3 Baseflow	55
2.5 Drought and Climatic Change.....	67
3. Geological Settings	81
3.1 Previous Work.....	81
3.2 Stratigraphy	82
3.3 Lithology	83
3.3.1 Paleozoic Sedimentary Rocks	83
3.3.2 Mesozoic Sedimentary Rocks.....	83
3.3.3 Tertiary Volcanic and Sedimentary Rocks.....	84
3.3.4 Quaternary Volcanic and Sedimentary Rocks.....	87
3.4 Structure	88
3.5 Geological history.....	89
4. Engineering Geology	91
4.1 Data Acquisition	91
4.2 Data Processing	92
4.3 Compilation of the Engineering Geology Map.....	93
4.3.1 Information Layers	94
4.3.2 Models of Geologic Environment.....	98
4.4 Engineering Geology Map – Sheet 1 – Basic Units.....	100
4.4.1 Engineering Geology Provinces – Zones of the First Hierarchic Level	100
4.4.2 Basic Land Units – Zones of the Second Hierarchic Level.....	101
4.5 Engineering Geology Map – Sheet 2 – Geo-risk Susceptibility.....	108
4.5.1 Geo-risk Statistics.....	110
4.5.2 Description of Important Engineering Geology Units	117
5. Hydrogeology	141
5.1 Water Point Inventory	141
5.2 Hydrogeological Classification/Characterization	142
5.3 Elements of the Hydrogeological System of the Area (Aquifers and Aquitards).....	144

5.3.1 Extensive and Moderately Productive Porous Aquifers.....	145
5.3.2 Extensive and Highly Productive Fissured and Karstic Aquifers.....	146
5.3.3 Extensive and Moderately Productive Fissured and Mixed Aquifers of the Plateau Area	146
5.3.4 Extensive and Low Productive Fissured Aquifers.....	150
5.3.5 Aquitards and/or Minor Aquifers with Local and Limited Groundwater Resources	151
5.4 Hydrogeological Conceptual Model	152
5.5 Annual Recharge in the Area	153
5.6 Mathematical Groundwater Flow Modeling Using Processing Modflow	154
5.7 Mathematical Model of Beresa River.....	158
5.7.1 Input Data for the Model of Beresa – Conceptual Model.....	158
5.8 Mathematical Model of Chacha River	162
5.8.1 Input Data for the Model of Chacha – Conceptual Model.....	162
5.8.2 The Single-layer Model of Chacha	163
5.8.3 The Dual-layer Model of Chacha – Model Procedure and Results	167
5.9 Mathematical Model of the Jemma Basin.....	168
5.9.1 Conceptual Cross-section Model	168
5.9.2 3-D Model of Jemma Basin	172
6. Hydrogeochemistry.....	183
6.1 Sampling and Analysis	183
6.2 Classification of Natural Waters.....	183
6.2.1 Rain Water	187
6.2.2 Surface Water and Wastewater	188
6.2.3 Groundwater in Volcanic Rocks.....	188
6.2.4 Groundwater in Sedimentary Rocks.....	192
6.3 Water Quality.....	193
6.3.1 Domestic Use	193
6.3.2 Irrigation.....	194
6.3.3 Industrial Use.....	194
6.4 Mineral and Thermal Water	196
6.5 Isotopic Composition of Groundwater.....	198
7. Natural Resources of the Basin	199
7.1 Economic Geology	199
7.2 Water Resources.....	202
7.2.1 Surface Water Resources and Development	203
7.2.2 Groundwater Resources and Development	207
7.3 Human and Land Use Resources and Development.....	211
7.4 Wind and Solar Energy Development	212
7.5 Environmental Problems and Their Control / Management.....	212
7.6 Touristic Potential of the Area.....	218
<i>Conclusions.....</i>	<i>219</i>
<i>References</i>	<i>223</i>