

## DAFTAR ISI

|                                                                  | Halaman     |
|------------------------------------------------------------------|-------------|
| <b>HALAMAN JUDUL .....</b>                                       | <b>i</b>    |
| <b>LEMBAR PENGESAHAN .....</b>                                   | <b>ii</b>   |
| <b>PERNYATAAN KEASLIAN KARYA ILMIAH.....</b>                     | <b>iii</b>  |
| <b>HALAMAN PERSEMBAHAN.....</b>                                  | <b>iv</b>   |
| <b>PRAKATA .....</b>                                             | <b>v</b>    |
| <b>ABSTRAK .....</b>                                             | <b>vii</b>  |
| <b><i>ABSTRACT</i> .....</b>                                     | <b>viii</b> |
| <b>DAFTAR ISI .....</b>                                          | <b>ix</b>   |
| <b>DAFTAR GAMBAR.....</b>                                        | <b>xv</b>   |
| <b>DAFTAR TABEL.....</b>                                         | <b>xx</b>   |
| <b>DAFTAR SINGKATAN DAN LAMBANG .....</b>                        | <b>xxi</b>  |
| <b>BAB I PENDAHULUAN.....</b>                                    | <b>1</b>    |
| <b>I.1. Latar Belakang .....</b>                                 | <b>1</b>    |
| <b>I.2. Rumusan Masalah .....</b>                                | <b>2</b>    |
| <b>I.3. Tujuan .....</b>                                         | <b>3</b>    |
| <b>I.4. Batasan Masalah.....</b>                                 | <b>4</b>    |
| <b>I.5. Lokasi Penelitian .....</b>                              | <b>4</b>    |
| <b>I.6. Luaran Penelitian .....</b>                              | <b>5</b>    |
| <b>I.7. Manfaat Penelitian .....</b>                             | <b>5</b>    |
| <b>BAB II TINJAUAN PUSTAKA DAN LANDASAN TEORI.....</b>           | <b>7</b>    |
| <b>II.1. Geologi Regional Natuna Barat .....</b>                 | <b>7</b>    |
| II.1.1. Fisiografi Cekungan Natuna Barat.....                    | 7           |
| II.1.2. Evolusi Tektonik dan Struktur Cekungan Natuna Barat..... | 8           |
| II.1.2.1. Tektonik Cekungan Natuna Barat.....                    | 8           |
| II.1.2.2. Tatanan Struktural Cekungan Natuna Barat .....         | 12          |
| II.1.3. Stratigrafi Cekungan Natuna Barat .....                  | 15          |
| II.1.2.1. Urutan <i>Syn-Rift</i> (Lisu).....                     | 17          |

|           |                                                                                                                                                                       |    |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| i.        | Formasi Lama (Eosen Akhir – Oligosen Awal).....                                                                                                                       | 17 |
| ii.       | Formasi Benua (Oligosen Awal).....                                                                                                                                    | 17 |
| iii.      | Formasi Gabus Bawah (Oligosen Awal - Tengah).....                                                                                                                     | 18 |
| II.1.2.2. | Urutan <i>Post-Rift</i> (Pasca Lisu) .....                                                                                                                            | 19 |
| i.        | Formasi Keras (Oligosen Tengah - Akhir).....                                                                                                                          | 19 |
| ii.       | Formasi Gabus Atas (Oligosen Akhir - Miosen Awal).....                                                                                                                | 19 |
| II.1.2.3. | Urutan <i>Syn-Inversion</i> .....                                                                                                                                     | 20 |
| i.        | Formasi Barat (Miosen Awal).....                                                                                                                                      | 20 |
| ii.       | Formasi Arang (Miosen Awal - Tengah) .....                                                                                                                            | 21 |
| II.1.2.4. | Urutan <i>Post-Inversion</i> .....                                                                                                                                    | 21 |
| i.        | Formasi Muda (Miosen Akhir – Holosen) .....                                                                                                                           | 21 |
| II.2.     | Petroleum System Natuna Barat.....                                                                                                                                    | 22 |
| II.2.1.   | <i>Source Rock</i> (Batuan Induk) .....                                                                                                                               | 23 |
| II.2.2.   | Reservoir dan Seal .....                                                                                                                                              | 23 |
| II.2.3.   | <i>Trap</i> dan Migrasi.....                                                                                                                                          | 24 |
| II.2.4.   | Akumulasi Hidrokarbon.....                                                                                                                                            | 24 |
| II.3.     | Penelitian Terdahulu.....                                                                                                                                             | 25 |
| II.3.1.   | Quantitative Interpretation Using <i>Facies</i> -Based Seismic Inversion .                                                                                            | 25 |
| II.3.2.   | Three-Dimensional Modelling and Volumetric Analysis Using Seismic and Well Log Data at DINO Oil Field, Niger Delta Basin, Nigeria.....                                | 26 |
| II.3.3.   | Generating geologically realistic 3D reservoir <i>facies</i> models using deep learning of sedimentary <i>Architecture</i> with generative adversarial networks ..... | 27 |
| II.3.4.   | <i>Convolutional Neural Network</i> for Seismic <i>Impedance</i> Inversion ...                                                                                        | 29 |
| II.4.     | Well Logging.....                                                                                                                                                     | 30 |
| II.5.     | Log Triple Combo .....                                                                                                                                                | 30 |
| II.5.2.1. | Log Gamma Ray .....                                                                                                                                                   | 31 |
| II.5.2.2. | Log Resistivity .....                                                                                                                                                 | 33 |
| II.5.2.3. | Log Densitas .....                                                                                                                                                    | 33 |
| II.5.2.4. | Log Porositas Neutron .....                                                                                                                                           | 34 |
| II.5.2.   | Log Sonic .....                                                                                                                                                       | 36 |
| II.5.3.   | Log Caliper .....                                                                                                                                                     | 37 |
| II.6.     | Sequence Stratigrafi.....                                                                                                                                             | 37 |
| II.6.1.   | Ruang Akomodasi.....                                                                                                                                                  | 39 |
| II.6.2.   | Parasikuen .....                                                                                                                                                      | 40 |
| II.6.3.   | Parasikuen Set.....                                                                                                                                                   | 41 |

|                                                                 |    |
|-----------------------------------------------------------------|----|
| II.6.4. Sikuen .....                                            | 42 |
| II.6.5. Depositional <i>Sequence</i> (System Tract).....        | 44 |
| II.6.6. Kronostratigrafi.....                                   | 46 |
| II.6.2.1. <i>Sequence</i> Boundary (SB) .....                   | 46 |
| II.6.2.2. <i>Maximum Flooding Surface</i> (MFS) .....           | 46 |
| II.6.2.3. <i>Marine Floofing Surface</i> (FS).....              | 47 |
| II.6.2.4. <i>Transgressive Surface</i> (TS).....                | 47 |
| II.7. Fluvial System .....                                      | 47 |
| II.8. Metode Seismik Refleksi.....                              | 50 |
| II.9. Reservoir Hidrokarbon .....                               | 51 |
| II.9.1. Sifat Fisis Batuan .....                                | 52 |
| II.9.2.1. Volume <i>Shale</i> .....                             | 52 |
| II.9.2.2. Porositas .....                                       | 53 |
| i. Porositas Total ( $\phi_{total}$ ) .....                     | 53 |
| ii. Prositas Efektif .....                                      | 53 |
| II.9.2.3. Saturasi Air .....                                    | 54 |
| II.10. Komponen Seismik Refleksi .....                          | 55 |
| II.10.1. Impedansi Akuistik .....                               | 55 |
| II.10.2. Koefisien Refleksi.....                                | 56 |
| II.10.3. Polaritas dan Fasa .....                               | 57 |
| II.10.4. <i>Wavelet</i> .....                                   | 58 |
| II.10.5. Resolusi Seismik.....                                  | 59 |
| II.11. Well Seismic Tie .....                                   | 60 |
| II.11.1. <i>Checkshot</i> .....                                 | 63 |
| II.11.2. <i>Vertical Seismic Profile</i> .....                  | 64 |
| II.12. Inversi Seismik .....                                    | 64 |
| II.13. Atribut Seismik.....                                     | 65 |
| II.13.1. Atribut Amplitudo RMS ( <i>Root Mean Square</i> )..... | 66 |
| II.13.2. <i>Envelope</i> .....                                  | 67 |
| II.13.3. Sweetness .....                                        | 68 |
| II.13.4. <i>Instaneus Phase</i> .....                           | 68 |
| II.14. Machine Learning.....                                    | 69 |
| II.14.1. Python .....                                           | 70 |
| II.14.2. Scikit-Learn.....                                      | 71 |
| II.14.3. Numpy.....                                             | 71 |
| II.14.4. <i>Convolutional Neural Network</i> .....              | 71 |

|                                                                         |           |
|-------------------------------------------------------------------------|-----------|
| <b>BAB III METODOLOGI PENELITIAN .....</b>                              | <b>73</b> |
| III.1.    Metode Penelitian .....                                       | 73        |
| III.1.1. Pendekatan Penelitian .....                                    | 73        |
| III.1.2. Jenis Penelitian .....                                         | 73        |
| III.1.3. Metode Pengumpulan Data.....                                   | 73        |
| III.1.4. Metode Analisis Data .....                                     | 74        |
| III.2.    Tahapan Penelitian .....                                      | 75        |
| III.2.1. Diagram Alir Pengolahan .....                                  | 75        |
| III.2.2. Tahap Persiapan Data ( <i>Pre-Processing</i> ).....            | 76        |
| III.2.3. Tahap Pengumpulan Data.....                                    | 76        |
| III.2.4. Tahap Pengolahan Data .....                                    | 76        |
| <b>BAB IV PENGOLAHAN DAN PENYAJIAN DATA .....</b>                       | <b>78</b> |
| IV.1.    Pengolahan Data.....                                           | 78        |
| IV.1.1. Data Availability .....                                         | 78        |
| IV.1.2.1. Data Seismic.....                                             | 78        |
| IV.1.2.2. Data Sumur.....                                               | 80        |
| IV.1.2. Petrophysical Analysis .....                                    | 81        |
| IV.1.2.1. <i>Acoustic Impedance</i> Estimation .....                    | 82        |
| IV.1.2.2. <i>Volume Shale Estimation</i> .....                          | 83        |
| IV.1.2.3. <i>Total Porosity and Effective Porosity Estimation</i> ..... | 85        |
| IV.1.2.4. <i>Saturasi Water Estimation</i> .....                        | 86        |
| i.    Analisis Picket Plot untuk <i>Rw</i> :.....                       | 86        |
| ii.   Penentuan <i>Rsh</i> :.....                                       | 87        |
| IV.1.2.5. Sensitivity Analysis .....                                    | 88        |
| IV.1.2.6. <i>Cut-off Determination</i> .....                            | 92        |
| i.    Penentuan Interval Formasi ( <i>Zonation</i> ).....               | 93        |
| ii.   Perhitungan <i>Gross Thickness</i> per Formasi.....               | 93        |
| iii.  Aplikasi <i>Cut-off Volume Shale (VSh)</i> .....                  | 94        |
| iv.   Evaluasi Porositas Efektif ( <i>PHIE</i> ) .....                  | 94        |
| v.    Identifikasi <i>Net Sand</i> .....                                | 94        |
| vi.   Evaluasi <i>SWE</i> dan Penentuan <i>Pay Zone</i> .....           | 95        |
| IV.1.3. Well Seismic Tie .....                                          | 95        |
| IV.1.2.1. Ekstraksi <i>Wavelet</i> .....                                | 95        |
| IV.1.2.2. Sintetik <i>Seismic Seismogram</i> .....                      | 96        |
| i.    Kalibrasi <i>Checkshot</i> :.....                                 | 96        |

|                                         |                                                                        |            |
|-----------------------------------------|------------------------------------------------------------------------|------------|
| ii.                                     | Estimasi Impedansi Akustik (AI) dan Koefisien Refleksi (RC): ..        | 96         |
| iii.                                    | Konvolusi: .....                                                       | 96         |
| IV.1.2.3.                               | Kontrol Kualitas Hasil Korelasi .....                                  | 99         |
| IV.1.4.                                 | <i>Horizon and Fault Interpretation</i> .....                          | 99         |
| IV.1.5.                                 | <i>Time Structure Map</i> .....                                        | 105        |
| IV.1.6.                                 | <i>Time to Depth Conversion</i> .....                                  | 107        |
| IV.1.7.                                 | <i>Depth Structure Map</i> .....                                       | 109        |
| IV.1.8.                                 | <i>Atribute Extraction</i> .....                                       | 113        |
| IV.1.9.                                 | Machine learning Progress .....                                        | 114        |
| IV.1.2.1.                               | <i>Import Library</i> .....                                            | 115        |
| IV.1.2.2.                               | Pra-pemrosesan dan Penyajian data latih .....                          | 116        |
| i.                                      | Seleksi Fitur (Input).....                                             | 116        |
| ii.                                     | Penentuan Label (Output): .....                                        | 117        |
| iii.                                    | Pembagian Data.....                                                    | 118        |
| iv.                                     | Normalisasi Data .....                                                 | 119        |
| IV.1.2.3.                               | Desain dan Pelatihan Model CNN untuk Prediksi AI .....                 | 119        |
| i.                                      | Arsitektur Model .....                                                 | 119        |
| ii.                                     | Pelatihan Model.....                                                   | 120        |
| IV.1.2.4.                               | Hasil dan Validasi Prediksi AI .....                                   | 121        |
| IV.1.10.                                | <i>Seismic Inversion</i> .....                                         | 123        |
| IV.1.11.                                | Pengolahan dan Hasil Inversi Berbasis Perangkat Lunak .....            | 123        |
| i.                                      | Pembangunan Model Awal ( <i>Initial Model</i> ).....                   | 124        |
| ii.                                     | Validasi.....                                                          | 124        |
| iii.                                    | Hasil Inversi: .....                                                   | 127        |
| IV.1.12.                                | Deteksi Fluida.....                                                    | 127        |
| <b>BAB V HASIL DAN PEMBAHASAN .....</b> |                                                                        | <b>129</b> |
| V.1.                                    | Prediksi Reservoir dengan Penentuan Zona Net Pay dari Data Sumur ..... | 129        |
| V.1.1.                                  | <i>Petrophysical</i> .....                                             | 129        |
| V.1.2.                                  | <i>Lumping</i> Reservoir.....                                          | 133        |
| V.2.                                    | Facies Interpretation .....                                            | 136        |
| V.2.1.                                  | Atribut <i>Slicing</i> .....                                           | 136        |
| V.2.2.                                  | <i>Predict Lithofacies</i> .....                                       | 146        |
| V.3.                                    | Analisis Komparatif Performa Inversi: CNN vs. Konvensional .           | 151        |
| V.3.1.                                  | CNN Vs Konvensional .....                                              | 157        |

|                                         |                                                      |            |
|-----------------------------------------|------------------------------------------------------|------------|
| V.4.                                    | Validasi CNN Facies dari Hasil Inversi CNN .....     | 161        |
| V.5.                                    | Delineasi Area Prospektif Reservoir Hidrokarbon..... | 168        |
| V.5.1.                                  | <i>Fluid Detection Interpretation</i> .....          | 168        |
| <b>BAB VI KESIMPULAN DAN SARAN.....</b> |                                                      | <b>173</b> |
| VI.1.                                   | <b>Kesimpulan .....</b>                              | <b>173</b> |
| VI.2.                                   | <b>Saran.....</b>                                    | <b>173</b> |
| <b>DAFTAR PUSTAKA.....</b>              |                                                      | <b>175</b> |
| <b>LAMPIRAN</b>                         |                                                      |            |