The consequences of two key approximations of accretion-disc physics near black holes are studied in this thesis. First, the question of effective ``pseudo-Newtonian" potentials mimicking a black hole is investigated both through numerical simulations and analytical means, and second, the neglect of additional gravitating matter near accreted-upon black holes and its consequences are put to test.

After some broader discussion of integrability, resonance and chaos, a general "pseudo-Newtonian" limit for geodesic motion is derived, and applied for the case of null geodesics near a glowing toroid and for time-like geodesics in the Kerr metric. Afterwards, a new Newtonian gravitational potential for non-singular toroids is proposed and its usefulness for the so-called Weyl space-times is discussed. Finally, a new pseudo-Newtonian potential is introduced and applied alongside already known potentials in models of free test particle motion in the field of a black hole with a disc or ring, in complete analogy with previous exact-relativistic studies, and the previous conclusion of chaos in disc/ring-hole models is confirmed. Overall, the pseudo-Newtonian framework is able to reproduce a number of key features of the original systems with notable differences arising only as a consequence of extremely strong or singular perturbation of the black hole.