# Analytical Solution and Direct Numerical Simulations of Particulate Turbulent Flows in a Channel

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# Analytical solution and direct numerical simulations of particulate turbulent flows in a channel

A. Goals:

- To investigate the effects of various parameters (mainly turbulence and particles) on the vertical distribution of sediment concentration.
- Also of interest is the murky area of the bottom boundary condition for particles, which has been debated for decades.
- This project will use both analytical method and numerical simulations.

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## B. Brief Discription:

Engineers and scientists put forth an extensive research to obtain the solution of sediment transport problems; most of them are based on numerical, empirical, or semi-empirical approaches. The possibility of analytical solution is apparently overlooked. Later on, a special attention has been devoted on searching analytical solutions for suspended sediment transport in channels besides numerical simulations.

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## B. Brief Discription

The merits of analytical solution include deep understanding and describing physical phenomenon of the problem by taking into account all the parameters of problem and investigate their influence. Analytical solutions of sediment transport are valuable not only for the basic understanding of the transport process but also useful for validating numerical schemes.

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## C. Heights of Achievements this semester :

- We developed a new semi-analytical solution method- Generalized Integral Transform Technique (GITT) for the two dimensional steady state solution of suspended sediment concentration in open channel flows.
- We compare the results with previous works as well as with numerical (Finite difference and spectral ) method results.

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## C. Heights of Achievements this semester :

- Based on our work, I am going to present a paper "Analytical Solutions for the Suspended Sediment Transport in Channels using Generalized Integral Transform Technique (GITT)" on EWRI 2013 World Environmental & Water Resources Congress, Cincinnati, Ohio, May 20-24.
- I am studying the different computational fluid dynamic methods (DNS, RANS, LES) to perform the numerical simulations on OpenFOAM CFD toolbox.

- Representative Figures/Diagrams/Videos that highlight my research methodology and results:

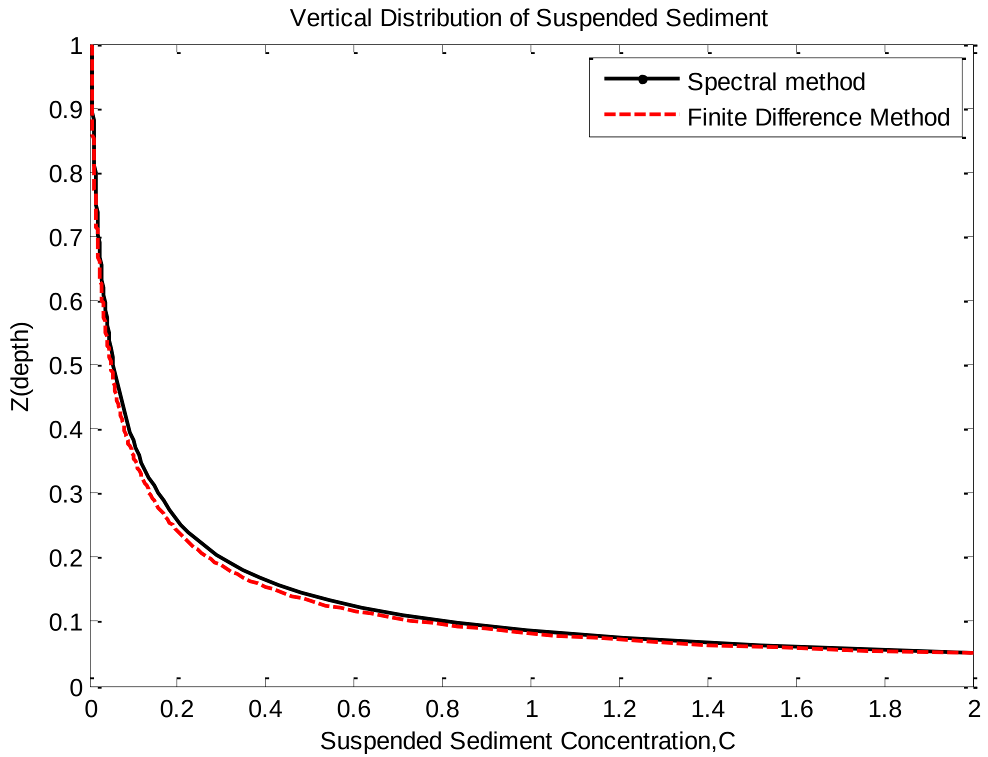


**Figure 1:** Comparison of numerical solutions for parabolic constant eddy viscosity with results using spectral and finite difference method.

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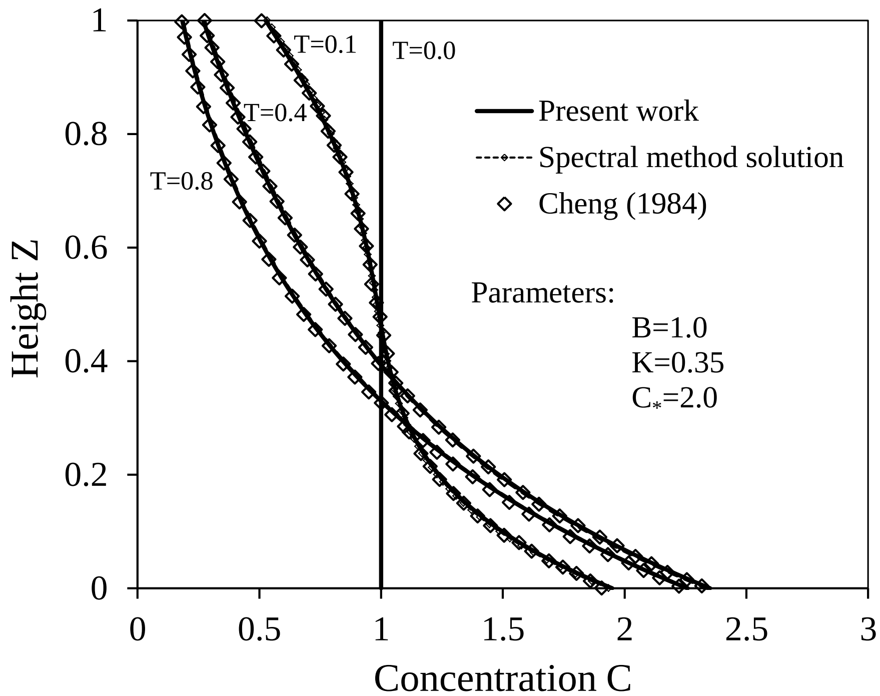


**Figure 2:** Comparison of analytical solutions for constant eddy viscosity with results using spectral method and those in Cheng (1984): $B = 1.0$, $K = 0.35$, $C* = 2.0$. Initial condition $C\,(T = 0, Z) = 1.0$. Note the overshooting of bottom boundary concentration.

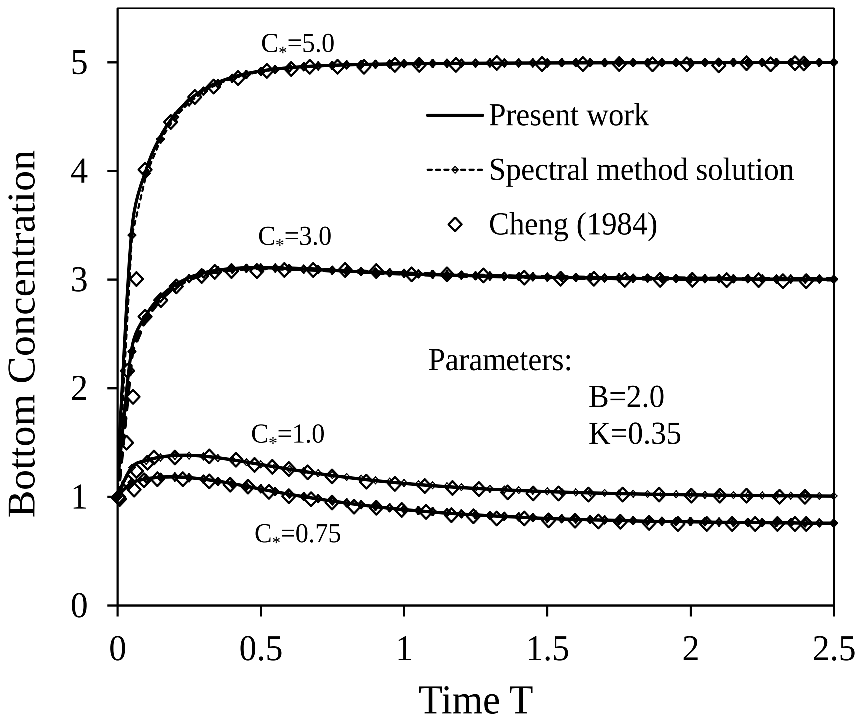


**Figure 3:** Comparison of analytical solutions for constant eddy viscosity with results using spectral method and those in Cheng (1984): Bottom concentration of sediment as function of time for various values of $C*$ for the constant eddy viscosity case. $B$ = 2.0, $K$ = 0.35.

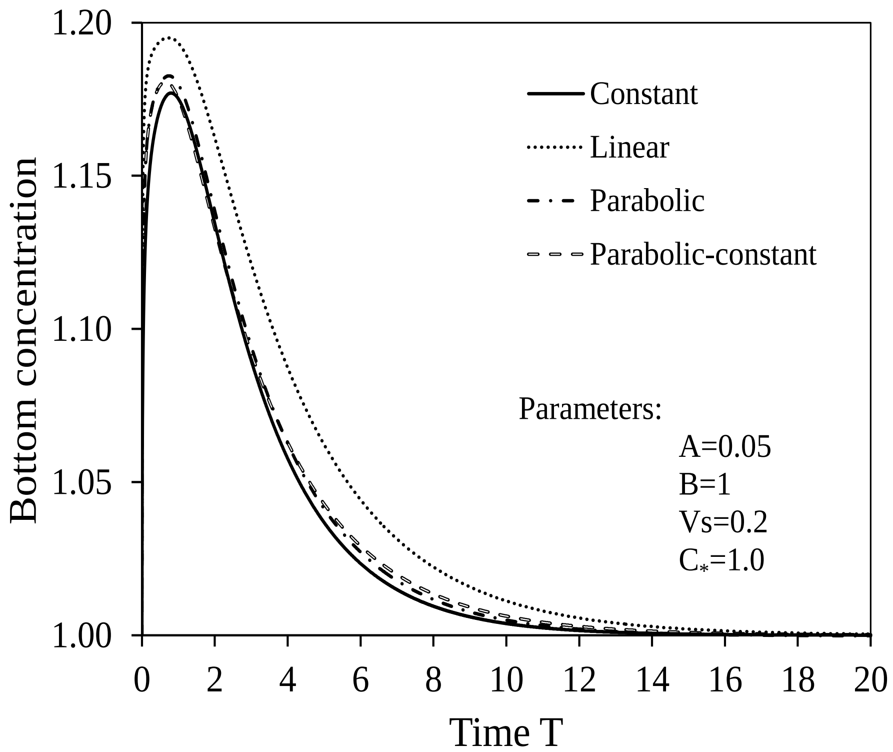


**Figure 4:** Adjustment of bottom boundary sediment concentration with different eddy viscosity distributions. $A$ = 0.05, $B$ = 1.0, $V_s$ = 0.2, and $C*$ = 1.0. Initial condition $C$ ($T$ = 0, $Z$) = 1.0.

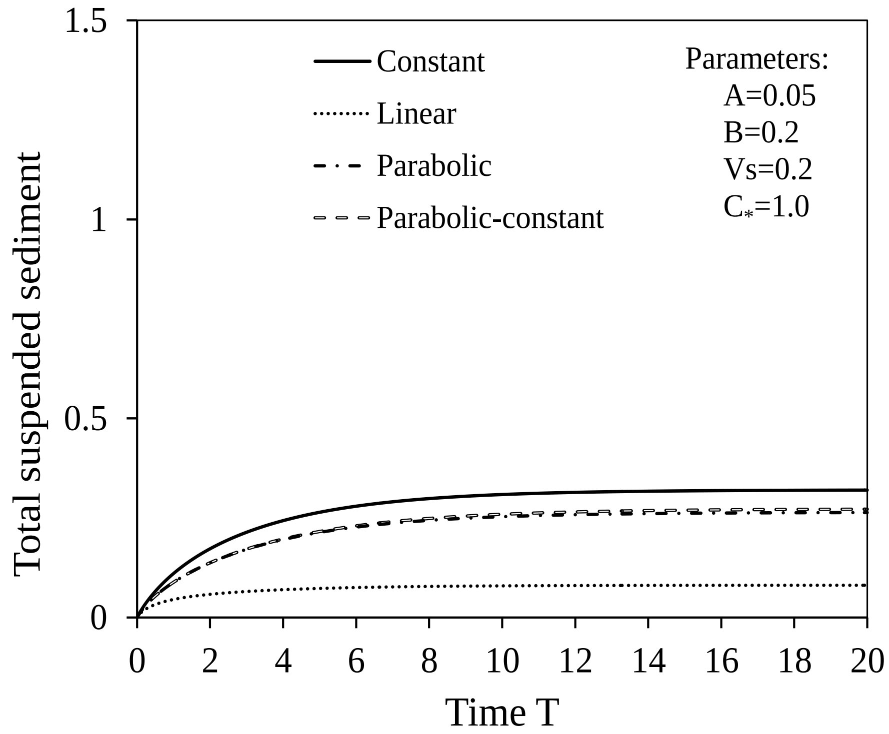


**Figure 5:** Total suspended sediment in the water column as function of time with different eddy viscosity distributions. $A = 0.05$, $B = 0.2$, $V_s = 0.2$, and $C* = 1.0$. Initial condition $C\ (T = 0, Z) = 0$.

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# Results:

- A very good agreement is achieved between our analytical results when compared with spectral method and the work done in Cheng (1984).
- This semi-analytical solution for unsteady suspended sediment transport in channels considering vertical variations of flow distribution and turbulent eddy viscosities.
- This analytical solution approach is very general and converges fast as the technique mitigates the error inherent in numerical solutions of the advection-diffusion equation.
- Therefore, we believe that the analytical solution (GITT) technique, besides the novelty of the semi-analytical character of the solution, is a valuable tool for suspended sediment (or any particulate matter) transport in channels.

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