DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
THE NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

A THREE-DIMENSIONAL NUMERICAL MODEL FOR SIMULATION OF SEDIMENT MOVEMENTS IN WATER INTAKES WITH MULTIBLOCK OPTION

SSIIM

User's Manual

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Foreword and history

The SSII program was developed in 1990-91 during the work with my dr. ing. degree at the Division of Hydraulic Engineering at the Norwegian Institute of Technology. SSII is an abbreviation for Sediment Simulation In Intakes. The program was originally built around the CFD program SPIDER, made by Prof. M. Melaaen during the work on his dr. ing. degree in 1989-90. SPIDER solves a flow problem for a general three-dimensional geometry. SSII was made up of sediment calculation routines for 3D solution of the convection-diffusion equation for the sediments, communications with SPIDER and a graphical user interface made in OS/2.

The main motivation for making SSII was the difficulty to simulate fine sediments in physical models. The fine sediments, often under 0.2 mm, are important for wear on turbines. It was also an advantage to be able to simulate other problems as for example sediment filling of reservoirs and channels.

After finishing my dissertation in 1991, I wanted to improve the CFD program. A disadvantage with the SSII and the SPIDER programs for practical situations was that a structured grid was used, and it was only possible to have one block for an outblocked region. A natural improvement was a multi-block model with general outblocking possibilities. This meant considerable changes in SPIDER. Instead, a new water flow module for multi-block calculation was made. This model was added to SSII, and the resulting model was called SSIIM.

SSIIM, version 1.0, was uploaded on the Internet 17th of June 1993. Version 1.1 had some bug-corrections and some improvements in the water flow calculation for multiple blocks. Version 1.1 was uploaded on the net 18th of October 1993. In the fall of 1993 version 1.2 was made, with an improved user interface, some additional tools and a revised manual. It was uploaded on the net 22nd of December 1993. It was also distributed by diskette to selected water institutions in January 1994. Version 1.3 included several bug-fixes, improved sediment calculation and improved graphics. This was uploaded on the net 5th of April 1994. Version 1.4 also included transient calculations of water flow, free surface and sediment transport, water quality, a 2D depth-averaged water flow module and improved graphics.

SSIIM version 1 uses a structured grid, which makes it difficult to model very complex geometries. In the summer of 1997 the main modules of SSIIM 2.0 was made, with an unstructured and nested grid. This was tested and enhanced during the following two years of my post-doc study in Bristol and Trondheim.

In the summer/fall 1999 both versions of SSIIM were ported from OS/2 to Windows. Version 1 was split into three executable: The grid editor, the OpenGL 3D graphics and the main program. SSIIM 2 had one executable, with the grid editor incorporated, and no OpenGL graphics. The OpenGL graphics was only supported on Windows NT, and omitting it in SSIIM meant that the program could be run on Windows 95 and Windows 98. The main advantages of the Windows version are more computers can run the program and the Windows version runs roughly twice as fast as the OS/2 version, probably due to the faster compiler. In SSIIM 1.1 for Windows, the Grid Editor was again included into the main program. The OpenGL graphics was a separate program: si3dview. In 2001, algorithms were made that printed out files that could be read directly by the Tecplot program. This program is commercially

available, and has good visualization possibilities, including 3D views. The si3dview program is therefore not planned to be updated. In the spring 2007, algorithms for writing input files for the ParaView program was added. The ParaView program is similar to Tecplot, but it is freeware. Also, algorithms to write an OpenFOAM mesh was added in the spring 2007. OpenFOAM is a general-purpose CFD program that is also freeware, with available source code and many more turbulence models than SSIIM. Unfortunately, the input format for the OpenFOAM files changed over time, so these functions are no longer compatible with the latest OpenFOAM version.

In the spring 2001, the Windows versions of SSIIM was made with DLL libraries. DLL is an abbreviation for Dynamic Link Libraries. DLLs containing numerical algorithms for sediment transport and flow resistance from vegetation were made. The DLLs may be further developed by cooperating research groups. In 2005, the source code for the beddll.dll file was made available on the web.

A native Linux version of SSIIM 1 without user interface was made in 2005, and made available on our web pages. The source code for this version is almost identical to the Windows source code for the computational part. It is planned that the Linux version will be updated, but with less frequent intervals than the Windows version.

In the summer 2007, work was started on parallel versions of the SSIIM programs. Implementation was done by using OpenMP. This enabled the utilization of multi-core capabilities of the emerging processors. It also enabled the use of the program on high-performance clusters with shared memory nodes. Initial work on an MPI version of SSIIM 2 was started in the fall 2012.

From 2010, the nested grid option was further developed in connection with sediment transport computations. The main application was local scour. In 2013, algorithms to compute geotechnical sand slides were coded. These algorithms were further expanded in 2018.

New algorithms for the free surface was developed in 2014. Algorithms for dredging of a reservoir/river was made in 2017, including the use of the “bagger” file.

In 2017, the computer I used to program SSIIM on broke down after 10 years of service. I wanted to move to more open source tools, so I switched the compiler and the IDE to GNU C++ and CodeBlocks. This meant rewriting the user interface of the program. This is considerable work, but it also means the possibility to improve the SSIIM graphics. Multiple windows can be shown at the same time, similar to the earlier OS/2 version of SSIIM. The new computer is 64 bits, meaning that future versions of 32 bits SSIIM may not be made. The use of CodeBlocks for making the user interface also means that it should not be too difficult to port the whole program to Linux at some point in the future. For example when the 2017 computer breaks down.

Further planned developments of the numerical algorithms include multiple bed sediment layers and prediction of sediment lamination. Also, modeling of stratified lakes/reservoirs may be revisited with improved functions for reduction of false diffusion.

Over the last years I have been working on web pages for my research on CFD using SSIIM. The address of the page is http://folk.ntnu.no/nilsol/cfd. News about applications, books, SSIIM versions etc. will usually be posted there. There are also information about some cases at the web pages http://pvv.org/~nilsol.

I would like to thank all the people who have provided me with insight into the various problems I have encountered in the development of this program. I have benefited greatly from the knowledge of Prof. Morten Melaaen at Telemark Institute of Technology, in the science of computational fluid dynamics. In the topics of hydraulics and sedimentation engineering I have learned from Prof. Dagfinn Lysne at Division of Hydraulic and Environmental Engineering at the Norwegian University of Science and Technology, and from Prof. Pierre Julien, Prof. Johannes Gessler, Prof. Ellen Wohl and Prof. Bogusz Bienkjewicz at Colorado State University. Torulf Tjomsland and Gosta Kjellberg from the Norwegian Institute of Water Research helped me with the biochemical models together with Glen George at the Institute of Freshwater Ecology, UK, Sally Heslop at University of Bristol and Richard Hedger at University of Edinburgh. Also thanks to Prof. Steve Chapra for his advice and excellent book on water quality modelling. Knut Alfredsen at the Norwegian University of Science and Technology helped me with software and hardware problems during the work with my dissertation, making the SSII model. Vijaya K. Singh at IBM Canada helped me with the C compiler. Dave Zenz and Suzy Deffeyes at IBM Visual Systems helped me with the OpenGL graphics. I would also like to thank the following people for helping me test the program: Morten Skoglund, Oscar Jimenez, Aslak Løvoll, Lars Abrahamsen, Siri Stokseth, J. Chandrashekhar, Knut Alfredsen, Hild Andreassen, Hilde Marie Kjellesvig, Md. Mahbubur Rahman, Tuva Cathrine Daae, Anne Sintic, Atle Harby, Amirul Islam Khan, Noor Quasim Khan, Chris Bowles, Catherine A. M. E. Wilson, Per-Ludvig Bjerke, Yaw Okyere, S. M. A. Azim, Ishfaq Ahmed, Tor-Haakon Bakken, Josip Jugovic, Sebastian Palt, Thorsten Stosser, Richard Hedger, Roland Parrot, Koen Blanchaert, Istiarto Istiarto, Ahmed Siyam, Tom Bryant, Peter Borsanyi, Hans-Petter Fjeldstad, Chris Whitlow, Doug Booker, Mohammad Irfan, Pravin Raj Aryal, Michael Abebe Haile, Harsha Suriyaarachchi, Tim Fischer-Antze, Lars Jensen, Susanne Krüger, Sabine Sultzer, Felix Hermann, Beate Kohler, Faruk Bhuiyan, Philip Soar, Georg Premstaller, Michael Tritthart, Dania Huggins, Juan Carlos Atoche, Ricardo Mantilla, Nils Ruther, Ingerid Pegg, Oral Yagci, Sandor Baranya, Nasib Man Pradan, Jagadishwar Man Singh, Åsta Gurandsrud, Jerome Molliex, Morten Stickler, Jorn Wildhagen, Rami Malki, Aravind Kumar Agrawal, Juan Martin Viscardi, Robert Feurich, Nadine Kilsby, Hans Bihs, Peggy Zinke, Zafer Defne, Desislava Balzhieva, Dejana Djordjevic, Annette Schulte-Rentrop, Clemens Dorfmann, Mostafa Jalali, Ursula Stephan, Christine Sindelar, Christoph Ortner, Gudrun Hillebrand, Stefan Haun, Lisa Emilie Hoven, Marc Roberts, Irina Klassen, Gabriele Harb, Laura Nardi, Sigurd Løvfall, Markus Noack, Christian Svensson, Halvor Kjærås, Sandeep Bomminayuni, Qing Zhang and Yannick Baulig. Also thanks to Richard Hibbert, David Seed, Richard May, Luca Barone, Isabelle Lavedrine, Norbert Jamot and Fabio Spaliviero at HR Wallingford Ltd., U.K. for their input and evaluation reports on SSIIM. Special thanks to Prof. Wolfgang Rodi, Prof. Gerhard Jirka, Prof. Roger Falconer, Thorsten Stosser, Catherine Wilson, Jan Wissink, Dominic von Terzi, Manuel Garcia-Villalba and Clemens Braun for advice on numerical algorithms and other assistance for the work during my sabbatical stay in Cardiff and Karlsruhe 2005/2006. I am also greatful for all the assistance from staff and fellow researchers at the Bundesanstalt fur Gewasserkunde in Koblenz, Germany, during my sabbatical in 2012/2013: Dr. Stefan Vollmer, Dr. Gudrun Hillebrand, Irina Klassen, Marc Roberts, Marcus Noack and Christian Svensson.

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Nils Reidar Boe Olsen

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Chapter 1. Introduction

1.1 Disclaimer and legal matters

I disclaim all warranties with regard to this software and the information in this document, whether expressed or implied, including without limitation, warranties of fitness and merchantability. In no event shall I or my employer be liable for any special, indirect or consequential damages or any damages whatsoever resulting from loss of use, data or profits, whether in an action of contract, negligence or other tortuous action, arising out of or in connection with the use or performance of this software. The program contains a number of bugs. It is not recommended that the program be used for solving a problem whose incorrect solution could lead to injury to a person, loss of property or economical losses. If you do use the program in such a manner, it is at your own risk. It is necessary to know that to understand and interpret the program results properly it is required that the user have knowledge and experience in computational fluid dynamics and hydraulic engineering.

If results from SSIIM are used in a scientific publication, references to earlier SSIIM work should be given so that the reader will understand that the SSIIM program has been used.

Provided the user complies with the above statements, the program can be used freely. The program can be distributed freely on condition that an unchanged copy of this manual is distributed with the program.

Nils Reidar B. Olsen

1.2 Limitations of the program and known bugs

Some of the limitations of the program are listed below.

* The program neglects non-orthogonal diffusive terms.
* The grid lines in the vertical direction have to be exactly vertical.
* Kinematic viscosity of the fluid is equivalent to water at 20 degrees Centigrade. This is hard-coded and can not be changed.
* The program is not made for the marine environment, so all effects of density gradients due to salinity gradients are not taken into account.

In computer science, a very well tested program still contains about one bug pr. 2000 lines of source code. The SSIIM programs contains over 100 000 lines of source code, and several modules have not been much tested. Also, combinations of modules may not have been tested at all. It is therefore likely that there are a number of bugs in the program. The user is advised to take this into consideration when evaluating the results of the program.

If the user publish results where the SSIIM model has been used, the user should include in the publication a statement that says that the SSIIM model has been used.

Provided the user complies with the above statements, the program can be used freely. The program can be distributed freely on condition that this disclaimer and an unchanged copy of the User's Manual is distributed with the program.

Some problems are also described in more detail in Chapter 2.15.

If you find any serious bugs that are not mentioned above, I would appreciate if you let me know. Please use the following address:

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1.3 Model purpose

SSIIM is an abbreviation for Sediment Simulation In Intakes with Multiblock option. The program is made for use in River/Environmental/Hydraulic/Sedimentation Engineering. Initially, the main motivation for creating the program was to simulate the sediment movements in general river/channel geometries. This has shown to be difficult to do in physical model studies for fine sediments. Later, the use of the program has been extended to other hydraulic engineering topics, for example spillway modelling, head loss in tunnels, stage-discharge relationships in rivers and turbidity currents. However, the main focus of the program is to model sediment transport in rivers, reservoirs and around hydrualic structures.

The main strength of SSIIM compared to general-purpose CFD programs is the capability of modelling sediment transport with moveable bed in a complex geometry. This includes a number of algorithms for different sediment processesizes, including sorting, bed load and suspended load, bed forms and effects of sloping beds. The latest modules for wetting and drying in the unstructured grid further enables complex geomorphological modelling.

Over the years, SSIIM has also been used for habitat studies in rivers, mainly for salmon. Free-flowing algae has also been modelled, as a part of extending the model for use in water quality engineering. However, the main focus of our research is on sediment transport.

The program is made for teaching and research purposes. It is not as well tested as commercial CFD programs, meaning it will have more bugs and be less reliable.

1.4 Model overview

The SSIIM program computes the water velocities and sediment transport in rivers, channels and reservoirs. The Navier-Stokes equations are solved with the k-e turbulence model on a three-dimensional almost general non-orthogonal grid. The velocities are used when solving the convection-diffusion equations for different sediment sizes. This gives trap efficiency and sediment deposition pattern. Bed changes over time can be computed, together with movement of the free water surface.

As with other multi-dimensional numerical models, SSIIM is divided into three parts: A pre-processor, a solver and a post-processor. The pre-processor includes tools to generate input data, including the computational grid. There is an interactive graphical grid editor with elliptic and transfinite interpolation together with a discharge editor. Grid can be generated on the basis of measured geometry data.

The user interface of the program can present velocity vectors and scaler variables in a two-dimensional view of the three-dimensional grid, in plan view, a cross-section or a longitudinal profile. It is possible to export results to programs as Tecplot or ParaView for post-processing.

The results can be viewed in the SSIIM graphics during the solution of the equations. Also, print-out of result files can be done from the menu.

New users are recommended to read Chapter 2.1 which gives more details and advice. It is also recommended to try the tutorials described in Chapter 2.

1.5 A guide to the different SSIIM versions

Before starting to use SSIIM, a decision has to be made about which version to use. There are two main versions of SSIIM: SSIIM 1 and SSIIM 2. SSIIM 1 uses a structured grid and SSIIM 2 uses an unstructured grid. Each of the programs is divided in two modules: A user interface and numerical algorithms. There are SSIIM versions both with and without the user interface. Since the user interface is made in Windows, versions running natively on Unix are without user interface. There are also both 32 bits and 64 bits versions of the Windows versions. The main difference is that 32 bits versions can only access 2 GB RAM, which means the maximum number cells is about 2 million. The 64 bits versions do not have this limitation. From a practical point of view, the amount of RAM in the computer limits the grid size of the 64 bits versions.

The programs can also be compiled to run with or without DLL's (Dynamic Link Libraries). The DLL's are modules where other programmers can code new algorithms and formulas, for example a formula for the sediment transport capacity. The DLL's only work on Windows, so all UNIX versions are compiled without DLL's.

There are different versions of SSIIM for parallel computations on clusters. The web page where the model is downloaded gives more information:

http://folk.ntnu.no/nilsol/ssiim

Structured vs. unstructured grids

In the structured 3D grid used by SSIIM 1, each cell will have three indexes, making it easy to identify grid locations. The location of walls and inflow/outflow surfaces are then specified in input files, where the grid indexes are included in the data set.

In the unstructured grid of SSIIM 2 this is not possible, as the grid cells only have one index. The user then has to specify the inflow and outflow areas by the use of a graphical discharge editor. This editor does not exist for the structured grid versions. Also, the grid editor for the unstructured grid includes the possibility of generating and connecting multiple blocks. The structured grid editor only works on one block.

The speed of the computation will often be better for the structured grid version, as faster solvers are available. The structured grid will also use less memory pr. cell, as connections between cells, surfaces and geometry points are simpler. SSIIM 2 has some water quality and sediment transport algorithms that are not in SSIIM 1. The main advantage of the unstructured version is its ability to model complex geometries and its algorithms for wetting/drying. Lateral movements of a river can only be modelled with SSIIM 2.

SSIIM 1 with the structured grid is easier to understand, intially. It is therefore recommended to start using this version. SSIIM 2 is more under development than SSIIM 1, which means SSIIM 2 will generally have more bugs.

It is possible to generate a grid in SSIIM 1 and transfer it to SSIIM 2 or the other way around. See Appendix I for further details.

As a conclusion and quick guide: Use SSIIM 1 if possible, and only use SSIIM 2 if you have a very complex geometry and/or wetting/drying processes.

Chapter 2. Startup using SSIIM

2.1 Advice for new users

Before you use SSIIM, it is necessary to have a minumum knowledge about hydraulics, fluid mechanics, sediment transport and numerical modelling. It is recommended that courses are taken in these subjects at university level. Then it is advisable to start with reading this manual.

A CFD computation generally consists of three steps:

1. Pre-processing
2. Computations
3. Post-processing

Pre-processing is generation of grid and input files. The SSIIM models contains grid generators to assist in making grids. Post-processing is viewing the results of the model. There are some graphics to do this in the SSIIM models. But it is also possible to use other post-processing packages as Tecplot or ParaView. An introduction to the pre and post processing in SSIIM is given by the tutorials in Chapter 2.3 to 2.7.

The computations itself can be calculations of water velocity calculations, sediment flow, bed level changes, water level changes and/or water quality. Each calculation is done by a module in of SSIIM. Some of the modules can be started from the program menu. The different the calculations can be combined, for example the water flow, sediment flow and bed changes computations. This is further described in Chapter 2.2.

An advice for the first-time user is to run the tutorials described later in Chapter 2 and one of the example cases. Try to modify some of the parameters and run it again. Often the user wants to simulate a particular case. It is then advisable to try to find a similar example case and modify this step by step.

The next problem is then often regarding computational speed and convergence. The user is recommended to read Chapter 2.12 for advice on these issues.

The SSIIM program has many input and output files. One of the most important files is the *boogie* file, which is produced by SSIIM and contains error messages and other results. SSIIM includes some controls for input and checking of intermediate results. If any of these controls finds something wrong, an error message is written to the *boogie* file, and the program terminates. Therefore, if the program suddenly stops, and the main user interface disappears, check the *boogie* file for possible error messages. Also, some warning messages may be written to the *boogie* file if particular problems occur. Chapter 2.16 gives more advice for finding bugs in the program.

The hardware requirements for running the program are sufficient amount of RAM in the computer and the speed of the computer. In the beginning of the boogie file it is printed how much RAM the program

allocates for the arrays. This can be added to the RAM requirement for the program itself, about 4 MB, plus what the operating system requires. An estimate for the amount of RAM is thereby obtained. The harddisk is used as extra memory if there is not sufficient RAM. The penalty is that the program runs very much slower. This situation can be detected by observing if the system swaps to the harddisk while running only the SSIIM program. The water flow module may take up to several days to converge for some cases, even when there is enough RAM. The 32 bits versions of SSIIM can roughly handle 2 millon cells. If you need more cells, you have to use the 64 bits versions of SSIIM.

When you have gotten results from SSIIM, you need to interpret these. You should then think about:

- Possibilities of bugs in the program making errors
- Previous cases where the results have been compared with measurements
- Numerical errors, like false diffusion, grid independence, etc.
- Accuracy of input data and boundary conditions

Knowledge and experience in computational fluid dynamics and hydraulic engineering are essential for the assessment of the validity and accuracy of the results. Chapter 2.13 gives further assistance for interpreting the results.

2.2 Starting up: overview of steps

The SSIIM programs are made up of a number of modules that reads files, makes grids, calculates unknown parameters, write result files etc. Some of the modules are started automatically, and some need to be started by the user. The user has two options on how to start the modules:

1. Use the menu in the graphics user interface
2. Specify which modules are to be run in an input file.

Option 1 is described in Chapter 4. Option 2 requires that a file called *control* exist in the directory the program is run from, and that this file contains a data set called F 2. The *control* file can contain a number of data sets, most often identified with a capital letter and a number. Then data is given after the identificators. The F 2 data set contains a number of capital letters. For each letter, a computing module of SSIIM is started. See Chapter 5.3 for more details about the data sets in the *control* file.

Some of the SSIIM versions do not have a user interface. Then option 2 is the only possibility to start modules of the program. The Windows versions of SSIIM has user interfaces. It consist of a window which shows the grid or the results of the computations. At the top, there is a menu. The menu can be used to for example start computaitons, read/write files, change the view of the graphics or the parameters shown in the graphics. The first time user is recommended to start the program and try the different options to get to know the program.

1. Making/reading the grid

When the program is started, it automatically searches for the *control* file. If the file is found, it will use

the data from this file. What happens afterwards is different in SSIIM 1 and SSIIM 2.

SSIIM 1 will automatically look for the *koordina* file, which contains the grid. If it is not found, a dialog box will emerge and the user will be guided into making this file for a straight channel. The same thing happens if the *control* file is not found. The tutorials show how this process is done. SSIIM 1 will automatically read the *control* and *koordina* files at startup.

SSIIM 2 will not start up a dialog if any of the input files are not found. In SSIIM 2, the grid and information about inflow/outflow of water is given in a file called *unstruc*. This file is not automatically read. The user needs to make the program read the file by using the menu or the *F 2* data set in the *control* file. The parameter used in the *F 2* data set is *U*, meaning the letters *F 2 U* has to be given in the *control* file. Of course, the grid has to be made first. This is described in the tutorials.

There might be up to 10 letters on the *F 2* data set. The program will then read 10 characters after encountering *F 2* in the *control* file. It is therefore advisable to have a number of characters which are not capital letters on the line after the data set. Lower-case charachters in the *control* file will be ignored.

Also note that the *control* file is only read once: when the program starts. If the user changes something in the *control* file, the program has to be restarted for this change to have any effect.

2. Making computations

After the grid is made and read, the computations can be done. The question is then: What do you want to compute? There are a number of options:

a) Compute a steady water flow with fixed water surface and fixed bed
b) Compute stationary sediment flow with a fixed water surface and fixed bed
c) Compute stationary water flow with an unknown water surface and a fixed bed
d) Compute unsteady water flow with a moving water surface and fixed bed
e) Compute unsteady water flow and sediments with a fixed water surface and moving bed
f) Compute unsteady water flow and sediments with a moving water surface and moving bed
g) Compute unsteady water flow with a moving water surface and fixed bed where there is wetting and drying
h) Compute unsteady water flow with a moving water surface and moving bed where there is wetting and drying.

Options g) and h) are only possible with SSIIM 2, as wetting and drying is not included in SSIIM 1.

All algorithms dealing with time-dependent changes in water level or the bed level will introduce uncertainties. The algorithms will also cause computational time to increase, often with several orders of magnitude. If some of the variables can be assumed to be stationary over time, this is often a time saving option. This especially applies to the location of the bed and water surface.

Case a), c) and d)

To compute the water velocities, with and without changes in the discharge or free water surface, the

option *Compute->Waterflow* is to be used in the program menu. Or use the *F 2 W* data set in the *control* file. In SSIIM 2, the grid has to be read first, so the data set will be *F 2 UW*. To invoke algorithms changing the free water surface, more information is given in Chapter 2.2.

If the user want to start the computation with a previously computed water flow field stored in the result file, the file can be read first. This can be done from the menu or using an R in the F 2 data set. The data set will then be F 2 RW for SSIIM 1 or F 2 URW for SSIIM 2.

Case b)

A sediment computation require information about the sediments on data sets in the *control* file. The *S* data sets gives sediment size and fall velocity and the *I* data sets give inflow of sediments in kg/s. The *N* data sets gives information about different initial grain size distributions of the bed material and the *B* data sets tells where in the geometry the different distributions are. These data sets must be given with correct parameters.

The steady sediment flow is computed by the menu or the letter *S* in the *F 2* data set. An initialization of the sediment flow (giving values to the concentration in all cells based on the Hunter-Rouse distribution) is done by using the *I* letter on the *F 2* data set. The steady sediment flow will use a previously computed water flow field. In other words, the **water flow has to be computed first, and then the sediments**. On the *F 2* data set this will be *F 2 WIS* for SSIIM 1 or *F 2 UWIS* for SSIIM 2. However, usually the water flow computation takes much longer than the sediment computation. Normally, one might want to do several sediment computations with for example different transport formulas. Then one can do the water flow computation first, and store the flow field in the *result* file. Instead of recomputing the water flow field for each sediment computation, one can read the *result* file by giving an *R* on the *F 2* data set. This will then result in the following data sets: *F 2 RIS* for SSIIM 1 or *F 2 URIS* for SSIIM 2.

Note that it is also technically possible to <u>not</u> compute the water flow before the sediment computation. This will of course give a completely wrong result, as the sediment computations is based on a known water flow field.

Case e) and f)

A time-dependent computation of water and sediment transport require more data sets in the *control* file. First, the same data sets describing the sediments as given for case b) must be included. Also a time step has to be given, on the *F 33* data set. Then the *F 37* data set has to be used, typically with an integer 1 or 2. If a free water surface is to be computed, the *F 36* data set also has to be used, with the integer 2, for example. The computation itself is invoked by the letter *S* on the F 2 data set. The *F 2* data set might therefore be *F 2 RIS* for SSIIM 1 or F *2 URIS* for SSIIM 2. Starting with a previously computed flow field is optional, and so is the initialization of the sediment concentrations. The data set might therefore be *F 2 S* or *F 2 US*.

Any variation over time of the water level, water discharge or sediment inflow must be given in the *timei* file.

Case g) and h)

Cases with wetting and drying are the most complicated problems, and can only be computed with SSIIM 2. The main principle is to make a grid with SSIIM 2 that covers all areas, both wetted and dry. This grid is then stored in the *unstruc* file, which is used at startup of the computations. This file must not be overwritten later, when the grid shrinks. The file will contain information about the bed levels in areas that can dry up and later become wetted. If the water level is to be changed during the computation, the reference cell number on the *G 6* data set has to be taken from this initial grid.

Since the *unstruc* file has to cover all areas that can be wetted, the water level has to be high during the generation of the initial grid. If this is the physical situation we want to model, this is fine. For example, a drawdown of the water level in a reservoir. Algorithms has to be invoked that moves the water level down (*G 6* data set + *timei* file). However, sometimes the user want to start the computations with a lower water level. An example is the computation of the formation of a meandering channel. The initial channel will then move sideways in areas that were not wet at the start of the computation. To solve the problem, the following procedure can be used:

When the *unstruc* file is written, also a file called *koordina.t* is written automatically. This file is similar to the SSIIM 1 *koordina* file, but it contains both the bed and the water level. The water level is the last floating point on each line. The file can be edited with a spreadsheet and a user-specified water level can be given in this file. The file is then renamed *koordina* without extension, and placed in the same directory as the *unstruc* file. During startup, when SSIIM 2 reads the *unstruc* file, it will search for the *koordina* file and if it is found, it will automatically use the *koordina* water levels as initial values. The grid in the *unstruc* file must then be regenerated, which can be done automatically at startup by using an *F 112 1* data set in the *control* file. It is very important that a new *unstruc* file is not written from the program after this procedure, as the information about the initially dried up areas may then be lost.

The *control* file must contain the same information about the sediments as for the steady computations. Also, time-varying parameters must be given in the timei file.

A couple of more advice for these type of computations: Use the following data sets in the *control* file: *F 94* control the criteria for if a cell is wetted or dry, or if one or more cells are generated in the vertical direction. Use *F 201 1* to get smoother sides, *F 113 7* to avoid unphysical velocities in partially dry cells. Also, it is advisable to use the multi-grid solver to improve convergence. This is specified on the *F 168* and *K 5* data sets. If the program crashes, look at advice in Chapter 2.12. Chapter 2.11 gives more details about lateral grid movements.

3. Post-processing

The most convenient way to see the results is in the SSIIM graphics. The grid can be seen in a plan view (Map graphics), longitudinal profile or cross-section. Unlike most other CFD program, the SSIIM graphics shows the results simultaneously with the computation of the variables. Also, different variables can be chosen from the menu, for example velocity vectors, water depth etc. SSIIM will also write the velocity field to a file called *result*, which can be read back to the program. Using SSIIM without a user interface, the *result* file can be moved to a Windows computer and read by a SSIIM version that has a user interface. For sediment computations, SSIIM can produce a file called *bedres*, which contains the bed levels. This file can be read back by the program in a similar way as the result

file. For time-dependent computations, a series of *result* and/or *bedre*s files can be written. The increment for when these times should be written is given on the *P 10* data set.

More advanced post-processing packages are also supported: Tecplot and ParaView. The two programs can show 2D or 3D views of the grid and the variables. They can also be used for making animations. Input files for these two programs can be written from the user interface of the program or automatically for time-dependent computations. Use the F 48 data set to specify the type of file to be written.

The ParaView program is freeware, and can be downloaded from the Internet. It is very easy to install, and can do everything Tecplot can do.

Note that all SSIIM input files and results files are ASCII files. Files can be generated with a Linux version of SSIIM, and processed by a Windows version of ParaView. Or the other way around.

2.3 Tutorial 1. Channel contraction (SSIIM 1)

This tutorial is meant for first time users of the SSIIM program. The tutorial shows the main features of the user interface, with the presentation graphics, animation and grid editing. The user is not required to edit files, but some knowledge of grids is recommended. It is important to know the purpose of the *control* and *koordina* input files. During the tutorial the files will be made interactively. The tutorial does not show the more advanced features of the program, which necessitates editing of the input files.

The tutorial is divided in four stages. During the first stage the two input files are made. During the second stage the presentation graphics is shown. The third stage familiarizes the user with the grid editor. The animation graphics is shown in the fourth stage.

First stage

In this stage the two user input files *control* and *koordina* are made.

Start SSIIM from a directory where the files *control* and *koordina* do not exist. This is done by writing c:\path\ssiimwin <CR> when you are on this directory. The "path" is the path to where the executable program ssiimwin.exe is placed.

After this a dialog box shows up on the screen, where you have to give some parameters for the grid. Default values are present in the edit fields. Click on the edit field for number of cross-sections. Change this value from 4 to 13. Also change the number of lines in lateral direction from 4 to 9. The initial default grid is made is rectangular. You can choose a grid which is 11 meters long and 6 meters wide. Change value in the edit fields from 10.0 to 11.0 for the length and from 5.0 to 6.0 for the width. After this, push the OK button with the mouse. The *control* and *koordina* files are then automatically made, and written to the disk. Immediately afterwards the normal user interface for the program is shown and the program is started.

Second stage

In this stage we will solve the flow field for the given grid, and look at the results.

The main user interface is a window with a menu. The text in the window will show intermediate results from the calculations and other messages. The menu is used for graphics and starting different sub-modules of the SSIIM program.

In the first dialog box to make the *control* file, you gave the waterlevel and dimension of the geometry. A default water discharge of 1 m^3/s is used, together with a Strickler-Manning's equation of 50. This is all we need to calculate the flow field with the Navier-Stokes equations. To start the solution of the Navier- Stokes equations you select the option *Calculation* from the main menu. Then select *Waterflow-3D* from the pull-down menu. After this, push the F 10 button on the keyboard to see how the residuals develop. The window shows the residual for all the six partial differential equations that are solved for the water flow calculation. The water flow calculation is converged when all the residuals are under 10^{-3}.

After convergence, we want to see the results. Choose the *View* option of the main menu, and the Map option in the pull-down menu. This gives you a graphics view of the grid as seen from above. Choose Variable from the menu, and Velocity from the pull-down menu. Then you see the velocity vectors. You can scale and move the plot by using the <Page up>, <Page down> and arrow keys. You can also scale the velocity vectors by choosing *Scale* and *VarEnlarge/VarShrink*. And you can see the other parameters than the velocity by choosing different variables in the *Graph* pull-down menu.

The velocity vectors are not too exciting for this channel and to make a more complex flow pattern, you need to change the grid. This is done in the third stage.

Third stage

In this stage we will concentrate about the grid editor. Start the grid editor by choosing View from the main menu bar and *GridEditor* from the pull-down menu. Scale and move the window and the grid.

To edit the grid, you first choose some points which will not be affected by the interpolation routines. This is done in a special mode of the editor. This mode is invoked by choosing Define from the menu and *NoMovePoints* mode from the pull-down menu. To verify that this mode is chosen, the letters "*Point mode, 0*" is shown on the lower part of the window. The integer shows how many points you have chosen. We want to choose four points, all on the upper boundary of the grid. A point is chosen by clicking with the mouse

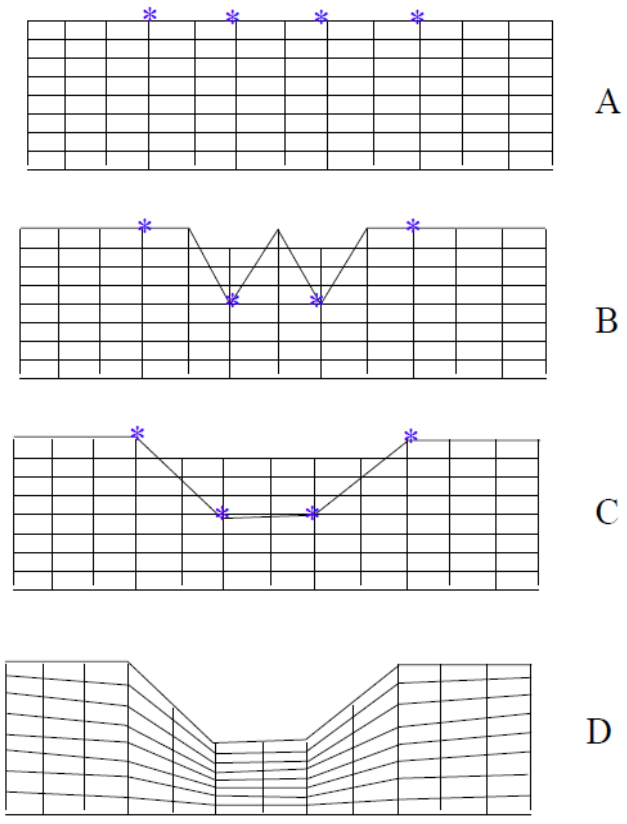


Fig. 2.3.1 Grid editor

on a grid intersection. If successful, a blue box emerges at the grid intersection. For a further explanation on which points to choose, see the figure on the right. After choosing the points we return to normal mode. This is done by choosing Define and Set *NoMovePoint* again. We observe that this mode disappears because the text "*Point mode, 4*" disappears.

Now we want to move the points. You can move any of the grid intersections by clicking on the intersection with the mouse and dragging it to another place and then release the mouse button. Try this with one of the intersections between the marked points. In the following the four marked points are denoted 1,2,3 and 4, starting from left. Move point 2 and 3 down midway into the channel. The grid should look like Fig. 2.3.1 B afterwards. Then choose *Generate* from the menu and *Boundary* from the pull-down menu. This makes straight lines at the boundary. The grid will look like Fig. 2.3.1 C. Now you see why we had to make the "NoMovePoints". Then choose *Generate* from the menu and *Elliptic* from the pull-down menu. Do this a couple of times until the grid looks ok. Now you have generated an elliptic grid, which looks something like Fig. 2.3.1 D.

To apply the changes from the grid editor, choose *Generate* from the menu and Implement from the pull-down menu. Then view the residuals again, by choosing *View->Text*. Start the water flow calculation by choosing *Calculation* from the main menu and *Waterflow-3D* from the pull-down menu. Push *F 10* repeatedly on the keyboard of your computer, and watch the residuals as the solution converges. Then watch the velocity vector field by choosing *View->Map* from the menu.

Fourth stage

In this stage we look at the animation. This is done by using the SSIIM OpenGL 3D Viewing programme. Exit SSIIM and start the program. The file is called *si3dview.exe*. It must be started from the same directory as we used previously.

After the program has started, choose *File->Read result.* The calculated velocity field is read. The grid seen from above is shown. Start the animation by choosing Particle in the menu and Run on the pull-down menu. Change the speed of the particles by changing the timestep. This is done by choosing *Define->Reduce time step* or *Define->Increase time step*.

2.4 Tutorial 2. Sand trap (SSIIM 1)

In this tutorial we will make a sand trap geometry, with a three-dimensional entrance region. Three-dimensional water flow will be simulated in the geometry and also sediment flow through the sand trap. The trap efficiency will be calculated from output of the boogie file. It is then necessary for the user to use an editor to see the content of this file, or a hard-copy can be printed. Otherwise, editing of the *koordina* and *control* files are not necessary.

Cases similar to this has been documented with comparisons with physical model tests by Olsen and Skoglund (1994) and Olsen and Chandrashekhar (1995).

Note that the number of grid cells for this case is very small because we want the solution to converge

rapidly. For a real case simulation this grid is too coarse, and many more cells should be used.

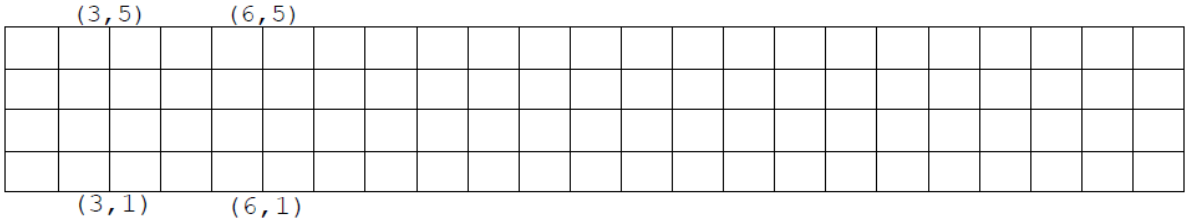
First stage - generation of grid

Start the SSIIM model from an empty directory with no *control* or *koordina* files - similarly to Tutorial 2.1. In the fist dialog box use a channel length of 20 meters and a channel width of 2 meters. The water level/depth is set to 2 meters, and we use 21 cross-sections, 5 points in each cross-section (lateral direction).

Then activate the *GridEditor* under the *View* choice in the main menu. Scale and move the grid until you see the grid in the center of the window. Then four *NoMovePoints* have to be inserted. These are given in the NoMovePoint mode, which is activated by choosing *Set NoMovePoint mode* in the *Define* menu. Then use the mouse and click on the following four grid line intersections:

3,1
6,1
3,5
6,5

These points are shown in the figure below.



If you click on the wrong place, use the *Delete NoMovePoint* option in the *Define* menu to remove the last point. After all four points have been given, set the mode back to normal by choosing *Set NoMovePoint* mode in the *Define* menu again

Now we want to make the inlet channel and entrance region. To do this, we need to move four points. These are the upstream corners and the two most upstream *NoMovePoints*. We use the *Give coordinates* in the *Define* menu option for this. When this menu choice is activated, a dialog box emerges. First, we change the coordinates of the grid intersection (1,1) to (0.0,0.5,1.0). This is done by clicking with the mouse on the grid intersection (1,1), and then choosing the *Give coordinates* option from the *Define* menu option. Give 0.0 in the *x*-coordinate edit field, 0.5 in the *y*-coordinate edit field and 1.0 in the *z*-coordinate edit field. Note that default values are given, so that the previous values have to be deleted from the edit field before inserting new numbers (if the defaults are not correct).

Do the same thing again, but change the line intersection (1,5) to (0.0,1.5,1.0), the line intersection (3,1) to (2.0,0.5,1.0) and the line intersection (3,5) to (2.0, 1.5,1.0). The two last intersections correspond to the *NoMovePoints*.

Afterwards, first choose *Boundary* in the *Generate* menu. Then choose *TransfiniteI* in the *Generate*

menu. This makes the two-dimensional grid. Then choose *Implementation* in the *Generate* menu option to generate a new three-dimensional grid.

Second stage - calculation of water flow

Go back to the main menu and look at a plan view of the grid, by choosing Map graphics from the View menu option. Then start the water flow calculations by choosing the *Waterflow-3D* option in the Calculate menu. View the residuals by choosing Text from the *View* option in the menu. Push F 10 on the computer keyboard to see the residuals while the program is calculating the flow field. It will take about 100 iterations to converge. Look at the resulting velocity field by the vector map or the longitudinal profile (*Map* or *Profile* in the *View* menu). Observe that the velocity vector field is non-symmetric at the bed.

Third stage - calculation of sediment flow

We need to give input data for the sediments. In the Windows version this must be done by giving the data in the *control* file. The file is edited using an editor, for example Notepad. Start Notepad, and read the *control* file from the directory you are working in. The *control* file contains several data sets, identified with a letter and number on each line. The *G 1* data set is already present in the file. It contains four integers, where the three first is the grid size. The fourth is the number of sediment sizes. The default is one. Change this to 2. Then the sediment characteristics should be given on the *S* data sets. These are not present initially, so you need to add these. Add the following lines:

S 1 0.0004 0.05
S 2 0.0001 0.007

The first index on the *S* data set is the number of the sediment fraction. The second is the diameter in meters and the third is the fall velocity in m/s. We use 0.4 mm for size 1 and 0.1 mm for size 2. As fall velocity, we choose 0.05 m/s for size 1 and 0.007 m/s for size 2.

It is also necessary to specify the sediment inflow. We choose to give 1 kg/s inflow for both sizes. The inflow is given on the I data sets as follows:

I 1 1.0
I 2 1.0

Save the file, and restart SSIIM. Then first compute the water velocity again, and then choose *Sediment* from the *Computations* menu in the main window. The sediment concentration is calculated. The sediment concentration results can be seen in the graphics by choosing Sediment concentration from the menu.

Fourth stage - calculation of trap efficiency

The trap efficiency is calculated from the fluxes, which are given in the *boogie* file. This file is approximately 213 lines long for this case. It is found in the same directory as we started from. It can be sent to a printer, or edited with an editor. In the middle of this file, we find the following:

****** In morphology ***********

Bed concentration flags: 0 0 0 0 0 0
Trap efficiency after 4 iter: all values in kg/s
l=1: Trapped: 0.973407, Fluxes (I1,I2,J1,J2): 1, 0.0264776, 0, 0 Resid: 0.000116
l=2: Trapped: 0.317048, Fluxes (I1,I2,J1,J2): 1, 0.671854, 0, 0 Resid: 0.011098

This means that of 1 kg/second inflow, 0.97 kg is trapped of size 1 and 0.32 kg is trapped for size 2. The total trap efficiency for both sizes is 65 %.

Note that the residual is still about 1 % for size 2. This means that the accuracy of the estimate for the trap efficiency can be increased by increasing the convergence criteria. This is done by changing the third parameter of the *F 4* data set in the *control* file, using an editor. A value of 0.0001 or 0.00001 instead of 0.01 gives a total trap efficiency of 62 %.

Also note that Tutorial 2.6 involves modelling a sand trap using SSIIM 2. It includes verification data from a laboratory model study.

2.5 Tutorial 3. Two-block grid (SSIIM 2)

This tutorial is meant for first time users of the SSIIM 2 program. The tutorial shows the main features of the user interface, with the grid editing and the presentation graphics. The user is not required to edit files, but some knowledge of grids is recommended. The tutorial does not show the more advanced features of the program, which necessitates editing of the input files.

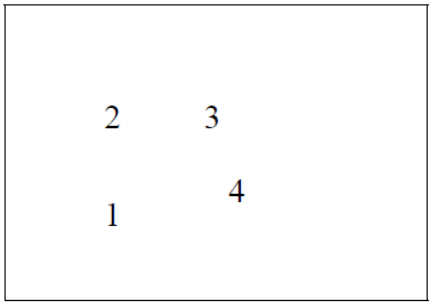
The tutorial is divided in four stages. During the first stage the grid is made. The second stage shows how to specify inflow/outflow water discharge. Then the calculations of the velocity flow field is made in the third stage. The presentation graphics is shown in the fourth stage.

The main user interface is a window with a menu. Choosing *Text* in the *View* option of the main menu, the intermediate results from the calculations and other messages are shown. The menu is also used for viewing graphics and starting different modules of the SSIIM program.

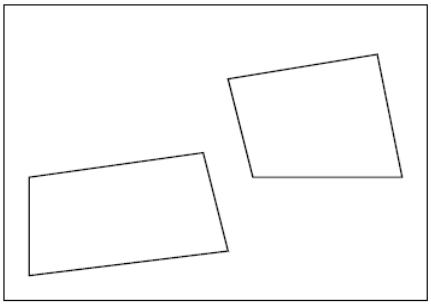
First stage - generating the grid

Start up SSIIM from a directory where the *control* and *koordina* files do not exist. This is done by writing c:\path\ssiim2w <CR> when you are on this directory. The "path" is here the path were the executable program ssiim2wn.exe is placed.

After the main window is shown on the screen, click on the *GridEditor* in the *View* option of the menu. This starts the grid editor, and a white area appear in the window where the grid is made. Click on Add block in the *Blocks* option in the menu. Then click on four points on the screen in the clockwise direction, as shown in the figure below:



Points in initial block

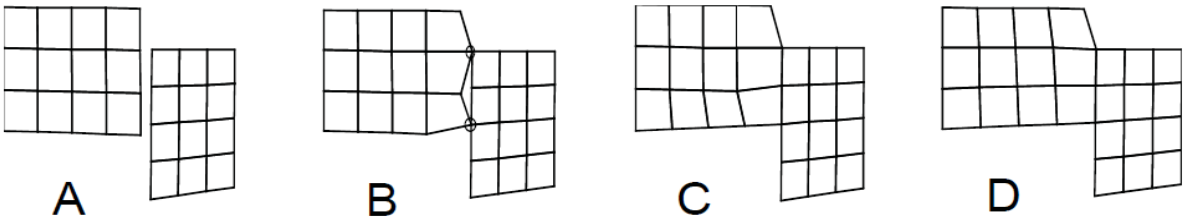


Location of the two blocks

After the rectangle is made, choose *Size* in the *Blocks* option in the menu. Click on *OK* in the dialog box that emerges. This gives the first grid block.

Then the second grid block is made in the same way. Place the second grid block according to the figure above.

Afterwards, choose *Connect points mode* in the *Blocks* menu. Then push the two grid intersections according to Fig. B below. Start with clicking on one grid intersection, and push it towards the intersection it is to connect to. The connection will then be shown with a yellow circle. If a mistake is made, choose *Delete last connection*, from the *Blocks* menu.



Then choose *Connect points* mode in the *Blocks* menu again, to get back to normal editing mode. Choose *Select block* in the *Blocks* menu, and select block no. 1. Then only this block is shown. Choose *Boundary* on the *Generate* menu. Then, choose *Elliptic* on the *Generate* menu. Again, choose *Select block* in the *Blocks* menu, and select block no. 2. Choose *Boundary* in the *Generate* menu. Then, choose *Elliptic* on the *Generate* menu. Finally, choose *Select block* on the *Blocks* menu and choose *All blocks*. Then the two blocks are seen, connected, like Fig. D above.

Then choose *3D Grid* on the *Generate* menu. This generates the 3D grid. The *unstruc* file can now be written from the *File* option of the main SSIIM 2 menu.

Second stage - specifying inflow and outflow

Start the program and read the previously generated unstruc file. Then choose View -> DischargeEditor. The grid seen from above emerges. Choose *Side Discharge -> Choose Group -> 1*. A dialog box emerges, where the water discharge is specified in m3/s. Give a value of 0.1 for the

inflow discharge. In the right editfield for the vertical cell: to: give 11. Then choose *OK*. Then click on two of the sides of the cells bordering the grid, at the left side. Once clicked, the lines change colour. Then choose *Side Discharge -> Group no. -> 2*. In the dialog box, click on the *Inflow* button. This specifies an outflow of the geometry. Give a value of 0.1 for the discharge. In the right editfield for the vertical cell: to: give in the number 11. Then choose *OK*. Click on two grid lines bordering the upper line of the geometry. The lines change colour, indicating outflow.

Note that it is possible to give up to 10 groups of water inflows and outflows. But the sum of the inflows have to be equal to the sum of the outflows.

Third stage - calculating the water flow

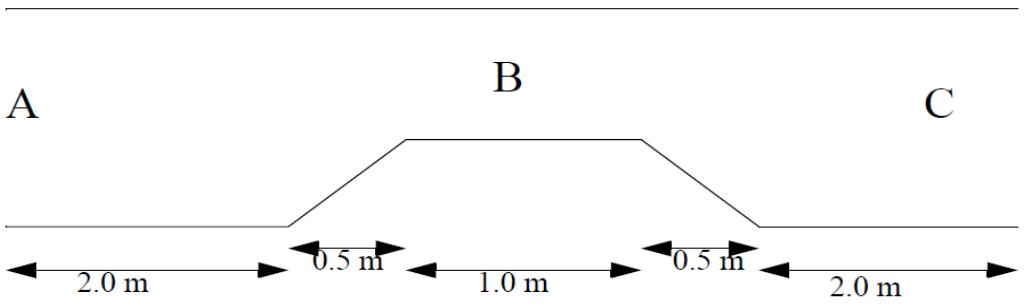
Choose *Text* from the *View* option in the menu. To start the solution of the Navier- Stokes equations you select the option *Compute->Waterflow* from the menu. After this, push F 10 on the keyboard to see how the residuals develop. The window shows the residual for all the six partial differential equations that are solved for the water flow calculation. The water flow calculation is converged when all the residuals are under 10^{-3}.

Fourth stage: viewing the results

The results are viewed by choosing one of the options in the *View* menu of the main user interface. Choose the *View* option of the main menu, and the *Map* option in the pull-down menu. This gives you a graphics view of the grid as seen from above. Choose *Variable* from the menu in the map window, and *Velocity vectors* from the pull-down menu. Then you see the velocity vectors. You can scale and move the plot by using the <Page up>, <Page down> and arrow keys on the keyboard. You can also scale the velocity vectors by choosing *Scale* and *VarEnlarge/VarShrink* from the menu. And you can see the other parameters than the velocity by choosing different variables in the *Variable* pull-down menu.

2.6 Tutorial 4. Scour in a contraction (SSIIM 1)

We will compute the erosion and deposition pattern in a flume with a contraction, initially covered with a flat sand bed. The figure below shows the flume seen from above:



The flume is 1 meter wide and 1 meter deep. The length is 6 meters. The inflow of water is in section A, and the outflow is in C. The flume width of the contraction in B is 0.5 meters. The water discharge is 1.0 m3/s, and the sediment size on the bed is 0.5 mm.

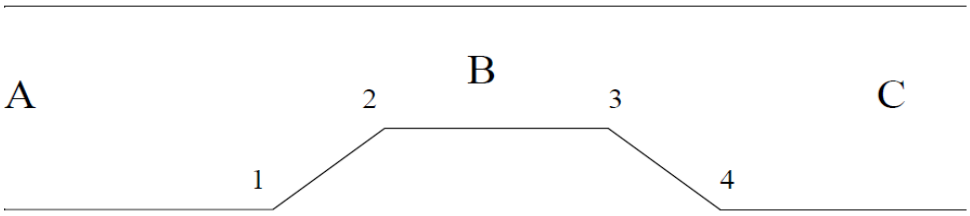
First stage: Generation of the grid.

Let us initially generate a relatively coarse grid, 60 cells in the longitudinal direction and 10 cells in the lateral direction. We start the program from an empty directory and a dialog box appears. In this we give the following parameters:

Length of initial channel (meters) 6
Width of initial channel (meters): 1
Water depth/level (meters): 1
Number of cross-sections: 61
Number of points in cross-sections: 11

Then press the OK button and the program starts. The length of the channel is 6 meters and the width is 1 meter. So is the water depth. The number of cross-sections is 61, one more than the number of cells. Similarly, the number of points in a cross-section is 11, one more than the number of cells we chose. The cells then become 10x10 cm, which makes it easier to generate the contraction.

We can look at the grid by choosing the menu option *View->Map*.



The geometry of the contraction is defined by the four points 1-4 in the figure below. To generate the contraction, we need to use the *Grid Editor*. This is started by choosing *View->GridEditor* in the menu.

The points 1-4 have to be defined in the grid editor, and straight lines need to be generated between them. This is done by first defining the four points as *NoMovePoints*. To do this, first choose *Define->NoMove Points Mode* in the menu. Then click with the mouse on the grid intersection close to point 1. Since point 1 is 2 meters from the entrance and the grid cells are 10 cm long, the point is located on the 21st cross-section. When you click on the correct point, the numbers 21,1 are shown in pink on the lower left corner of the window. If you clicked on the wrong point, then go to the menu and choose *Define->Delete last NoMove Point*. And try again. Then define point 2, located at 26,1, five cells downstream of point 1. Point 3 is located 10 cells downstream of point 2, and point 4 is located 5 cells downstream of point 3. The grid intersections for the points are:

Point 1: 21,1
Point 2: 26,1

Point 3: 36,1
Point 4: 41,1

When this is done, choose the menu option *Define->NoMove Points Mode* again, and it will be possible to click on the grid without generating new *NoMove Points*.

Then the exact coordinates for these four points must be given. Point 1 and 4 are already located at the correct position. But Point 2 and 3 needs to be moved towards the center of the channel. This is done by first clicking one of the points, for example Point 2. Then choose Define->Give coordinates. A dialog box appears. Then give the coordinates: x=2.5, y=0.5, z=0.0. Then click OK. The point is moved to the center of the channel. Then do the same with Point 3. The coordinates of this point is x=3.5, y=0.5, z=0.0. Then choose from the menu: Generate->Boundary and Generate->Transfinite I. Then choose Generate->Implementation. The last choice causes the koordina file to be written, with the generated geometry, together with a *control* file. It also initializes the water velocity in the geometry.

To compute the velocity field, choose the menu option *Calculation->Waterflow-3D*. The computation may not converge, as it may be necessary to modify the *control* file first.

Second stage: prepare the *control* file

Edit the *control* file with for example the Windows Notepad. The initial *control* file only has seven data sets. You may type a title on the first *T* data set in the file, but do not use capital letters.

The first thing to change is the vertical grid resolution. Initially, there are only 3 cells in the vertical direction. We increase this to 10. This is done by changing the *G 3* data set to:

G 3 0.0 10 20 30 40 50 60 70 80 90 100

And changing the third integer in the *G 1* data set from 4 to 11.

We give in an *F 4* data set, with the parameters:

F 4 0.8 20 0.00001

The second number in the data set, the integer, is the number of inner iterations in the sediment computation. The default is 500, which is too high when we only want to use one sediment size.

The *F* data sets are inserted between the *T* data set and the *G 1* data set in the file.

We want to do a time-dependent computation, and thus need to add a time step. This is done by inserting an *F 33* data set:

F 33 1.0 20

The time step is 1.0 seconds, with 20 inner iterations for each time step.

To specify that we want to do a time-dependent sediment computation, we insert *F 37 1* in the file.

To increase the convergence speed of the water flow computation, we use block-correction algorithms. Insert the *K 5 1 1 1 1 1* data set close to the end of the *control* file.

To start up the sediment computation right after we start the program, we insert

F 2 IS run choice

into the file. The *F 2* data set reads 10 characters. The letters IS tells the program to initiate the sediment computation and start the sediment calculation. Then eight more characters are read. It is therefore necessary to have some spaces or lowercase letters after the IS. Otherwise, the program will start to read the characters on the line below.

Then the sediment data are given on the *S, I, N* and *B* data sets. These data sets have to be given after the *G* data sets in the file. The sediment diameter and fall velocity is given on the *S* data set:

S 1 0.002 0.01

We have here specified a diameter of 2 mm and a fall velocity of 1 cm/s.

I 1 0.0

We have specified zero inflow of sediments

N 0 1 1.0

Sieve curve 0 has 1.0 or 100 % of size 1.

B 0 0 0 0 0 0

The whole bed is covered with sieve curve 0.

Save the *control* file.

Third stage: run the program

Start the program, and the sediment computation will start immediately due to the *F 2* data set.

Look at the results by choosing from the menu *View->Map*. Choose from the menu for example *Variable ->Bed changes*.

The program will run for 40 000 time steps, which is the first integer on the *K 1* data set. This may take some time, so you may want to stop the computation and give a lower value on this data set before restarting.

Fourth stage: parameter tests

The sediment transport computation is based on a number of empirical formulas. Some of the parameters in the formulas can be fairly uncertain. It is therefore important to do a parameter sensitivity test. Also, there are different numerical algorithms in the program, which will affect the results. These should also be included in the parameter test. The size of the grid should also be varied.

The following parameters can be tested:

Sediment formulas:

Use Shields curve for critical shear stress instead of a given Shields parameter (default 0.047): *F 11* data set.

Use bed load or suspended load formulas, or both: *F 84* data set

Change the parameters in van Rijn's formulas: *F 6* or *F 83* data sets

Thickness of active sediment layer: *F 106* data set

Include bed form effects: *F 90* data set

Decrease critical shear stress on sloping beds: *F 7 B* data set

Water flow formulas:

Manning-Stricklers friction coefficient: *W 1* data set, or the *F 16* data set.

Numerical algorithms:

Time step and number of inner iterations: *F 33* data set.

First order or second order upwind scheme: *K 6* data set: *K 6 1 1 1 0 0 0* recommended for second-order upwind scheme.

Grid size: For the current tutorial, regenerate the grid with larger number of cells. This will not take much time for the current simple geometry. However, for more complex geometries, it is possible to use the *F 7 DJ* options.

2.7 Tutorial 5: Flow in a bend with SSIIM 2

We will compute the water flow in a bend using SSIIM 2. The grid of the bend is made using a spreadsheet. The approach is to compute the coordinates of the sides of the bend using the spreadsheet, and to give these coordinates

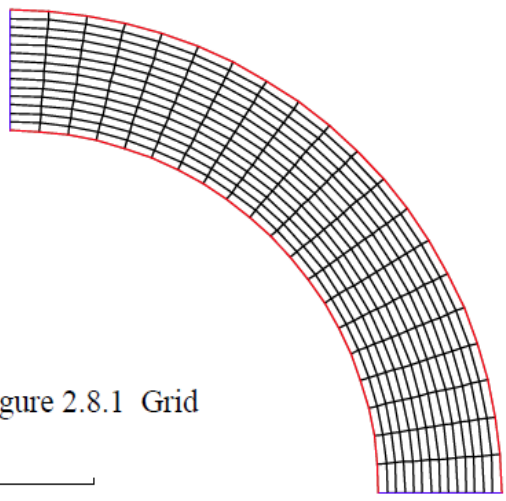


Figure 2.8.1 Grid

in a koosurf file. Also, the points on the sides are fixed defining them as *NoMovePoints*.

First, we decide for the dimensions of the channel and the grid size. We want to compute a 90 degree bend, with 21 grid lines in the streamwise direction and 15 grid lines in the cross-section. The inner radius of the bend is 3 meter and the outer radius is 4 meters, giving a channel width of 1 meter.

Step 1. Making the *koosurf* file.

With 21 grid lines over 90 degrees, each cell will have a sector of 90 / 20 = 4.5 degrees. The x coordinates of the grid line on the inner bank can then be computed by the following formula:

$$x = 3\sin(\alpha) \qquad (2.8.1)$$

$$x = 3\cos(\alpha) \qquad (2.8.2)$$

These formulas are then coded in the spreadsheet, where angle for each grid line is also given. The formula for the angle will start with zero for the first point, and then it will be the 4.5 degrees plus the value in the cell above.

The table below shows how the spreadsheet would be. The numbers are given for the first 6 points and the last point, i=21. Eq. 2.8.1 and Eq. 2.8.2 are used to compute the x and y values.

Table 1: Spreadsheet for computing the values in the *koosurf* file

i	j	x	y	z, bed	z, surface	angle,
1	1	0	3	0	1	0
2	1	0.2353	2.9907	0	1	0.078537
3	1	0.4692	2.9630	0	1	0.157075
4	1	0.7003	2.9171	0	1	0.235612
5	1	0.9270	2.8531	0	1	0.314150
6	1	1.1480	2.7716	0	1	0.392687
..	1	..	..	0	1	..
21	1	3	0	0	1	1.57075

The spreadsheet also needs to compute the similar coordinates for the outside bank of the channel. This will be the same as for the inside bank, except the radius will be 4 instead of 3 in Eqs. 2.8.1 and 2.8.2. And the j values will be 15 instead of 1.

After the spreadsheet is made, the content must be written to a file called "*koosurf*". This can be done in many ways, but one way is to open the Notepad program in Windows. Mark the areas from the spreadsheet and copy it into the Notepad. Only the *i,j,x,y,zbed* and *zsurface* must be copied, not the angle. Also, there must be one set of coordinates on each line, with no blank lines in between. Make sure there are six numbers on each line, otherwise there will be some problems later.

In Notepad, the file can be saved as *koosurf*. However, Notepad will add an extension .txt to the file name. This must be removed.

Step 2. Making the *control* file

The next thing to do is to make SSIIM 2 see these points as fixed points. This is done by making several *W 6* data sets in the *control* file. This is also most easily done in a spreadsheet. The following text must be made and inserted into the *control* file. Note that the *control* file also must be without extension. And at the present stage, it does not need to contain any other information than the *W 6* data sets. The file will then look like the following:

```
W     6     1     1
W     6     2     1
W     6     3     1
W     6     4     1
W     6     5     1
W     6     6     1
...
W     6     21    1
W     6     1     15
W     6     2     15
W     6     3     15
W     6     4     15
W     6     5     15
W     6     6     15
..
W     6     21    15
```

The points between i index 7 and 20 are not given above, but they have to be in the *control* file. The *control* file will then have 42 *W 6* data sets.

Step 3. Making the grid

Make a directory with the SSIIM 2 program and the *control* and *koosurf* file made earlier. Then start the SSIIM 2 program. From the main menu, choose *View* and *Grid Editor*. Then choose the menu option *Blocks* and *Add block from koosurf*. This may cause some grid lines and blue rectangles to appear in the window. Or not, it may be necessary to do some scaling with the *Page Down* button on the keyboard. The grid lines will look confusing, since we only have made the sides of the grid and not the grid interior. The rest of the grid is made by choosing from the menu: *Generate* and *boundary*, and then *Generate* and *TransfiniteI*. The grid then looks like Fig. 2.8.1.

To save the grid, use the menu option *Generate* and *3D grid*, and then *File* and *Write unstruc file*. After this, it is possible to end the program and restart it reading back the *unstruc* file from the menu.

Step 4. Specifying inflow and outflow discharges

From the menu, choose *View* and *Discharge Editor*. The grid appears, seen from above. From the menu, choose *Side discharge*, *Group no.* and *1*. A dialog box appears. In the edit field for *Discharge*, give in the number 1, for 1 m^3/s. Click on the *OK* button. Then from the menu, choose *Side discharge* and *Add area series 100*. Then scale and enlarge the grid in the *Discharge Editor* so that it looks like

the figure below. The click on the grid line pointed to with the red arrow.

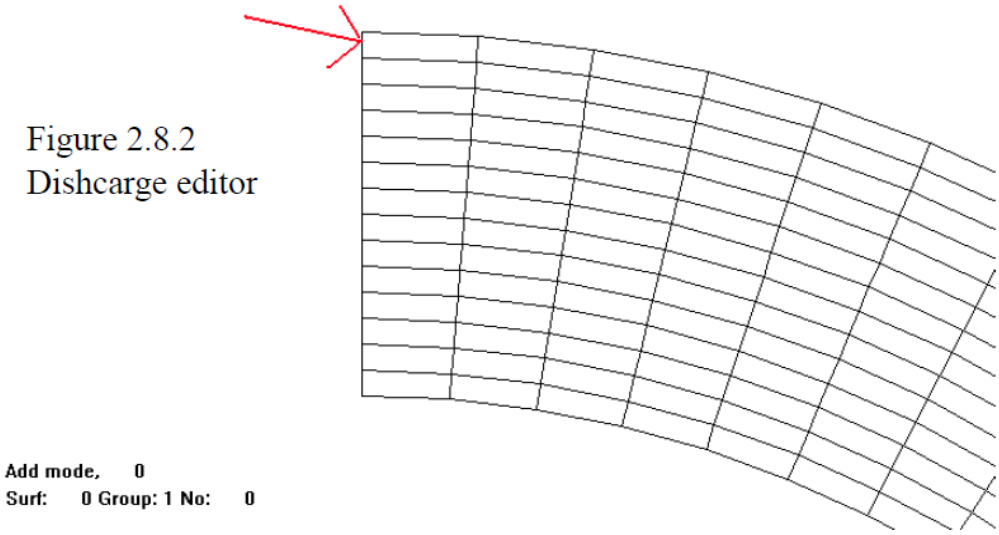


Figure 2.8.2
Dishcarge editor

This will cause the whole inflow cross-section to be colored blue. Note that we have clicked on the inflow side of the left bank cell. We repeat the same procedure for the outflow cross-section. Only now we choose the *Discharge Group 2* as outflow. In the dialog box, we cross off "*inflow*", meaning this will be outflow. And when we specify the outflow cross-section graphically, we have to use the right bank cell. Instead of the left bank cell that we used for the inflow.

If you do a mistake and only some of the cells have inflow or outflow, then go to the menu Side Discharge and choose Remove all areas. Then all areas in the group you are working with are removed. The areas in the other groups will not be affected.

After the discharge is specified, save the *unstruc* file from the menu: *File* and *Write unstruc*. The information about the discharges are in the *unstruc* file.

Step 5. Computing the water velocities

From the menu, choose *View* and *Map*. If you see the grid, then everything is ok and you can proceed. If you have just started the program and the grid is not made or generated, you need to go to the menu and choose *File* and *Read unstruc*.

From the menu, choose *View* and *Text*. Then choose *Compute* and *Waterflow*. Then push the F 10 button on the keyboard repeatedly. The window shows how the residuals decrease. When they are below 0.001, the program has converged. The water velocities have then been computed.

Step 6. Looking at the results

From the main menu, choose *View* and *Map*. Then choose *Variable* and *Surface+bed vectors*. Scale the vectors with the F7 and F8 keys on the keyboard until they are of appropriate length. Also, you can scale or move the view with the arrow keys and the keyboard keys PgUp and PgDn. See how the

secondary currents cause a deviation between the bed and surface velocity vectors at the end of the canal.

Then from the main menu choose *Sediment variable* and *Secondary current angle*. This shows the angle in degrees between the surface and bed vectors.

2.8 Tutorial 6. Natural river using SSIIM 2

We will compute the flow in a natural river using SSIIM 2. SSIIM 2 includes wetting and drying, and it is convenient to use this algorithm to get a grid that follows the bank of the river as the water level rises and sinks. This tutorial will only work directly with SSIIM 2 versions made after 12. December 2013. Earlier versions need to start with a *control* file that has the *F 64 11* data set.

Step 1. Making the grid

The geometry of a natural river is most often fairly complex. The most used way to describe the geometry is by measuring a large number of coordinates (x,y,z values) of points at the river bed. SSIIM use these points in a file called geodata. Each point is given on one line in the file, with the three floating point numbers, x,y and z. There has to be a capital E at the start of each line, before the numbers, and the numbers must be separated by one or more spaces.

In the present tutorial, we will use a geodata file made up from a virtual case. The file can be downloaded from the web page: http://folk.ntnu.no/nilsol/cases/tutorial_river/geodata.

Make a new directory on your PC, download this geodata file to the directory and also download SSIIM 2 with the DLL's to the same directory. Then start the program. In the main menu, go to View and Grid Editor. Then go to View and geodata points. The measured points now emerge in the window as seen in Fig. 2.9.1.

The colours of the geodata points shows the water depth. Red is high water depths and blue is low water depths. Green is in between blue and red. Fig. 2.9.1 shows that the river is flowing in a bend. We now assume the flow direction is from the top of the figure to the right in the figure.

The first thing we need to do is to make a grid block covering the river. This is done from the menu, by choosing Blocks and Add block. Then you click on the four corners of a structured grid.

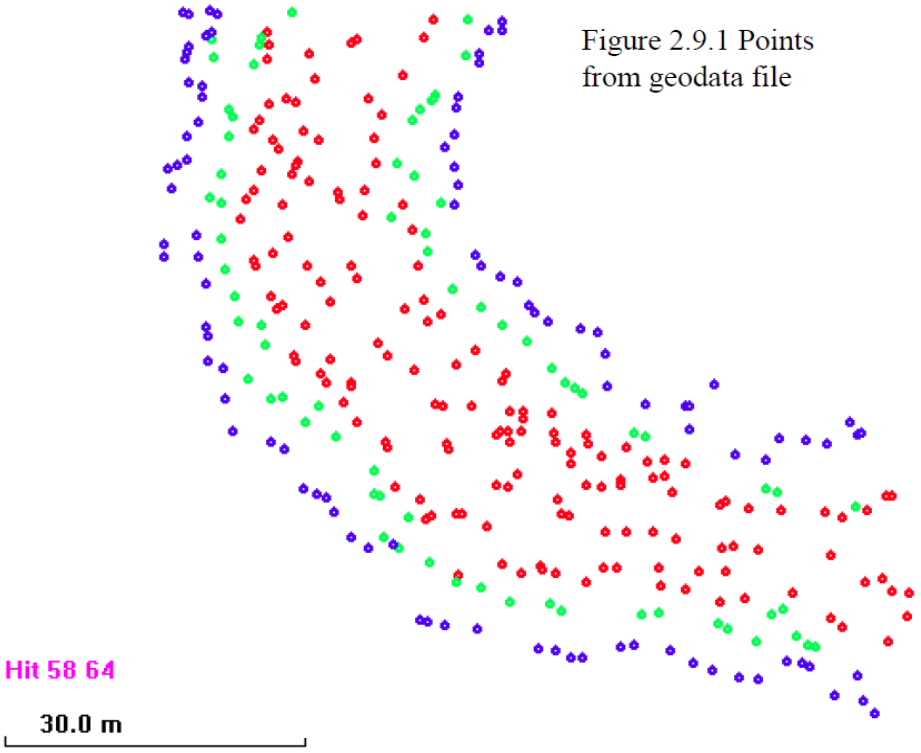


Figure 2.9.1 Points from geodata file

The first point should be on the right bank of the upstream cross-section. The second point on the left bank of the upstream cross-section. The third point on the left bank of the downstream cross-section and the fourth point on the right bank of the downstream cross-section. After clicking the second, third and fourth point, green lines emerge, which shows the border of the structured grid. This is shown in Fig. 2.9.2.

The first point will have the indexes (i=1,j=1). The second point will have indexes (i=1,j=nj), the third point will have indexes (i=ni,j=nj) and the fourth point will have indexes (i=nj, j=1). Here, ni is the number of cross-sections in the grid and nj is the number of points in each cross-section.

The next step is to fill this area with a structured grid. On the menu, choose Blocks and Size block. A dialog box emerges, with question about the grid size. Choose 71 lines in the i-direction (streamwise) and 21 lines in the j-direction (cross-section). Then click on OK and the grid is made as seen in the window.

This grid has straight sides and does not follow the river. To make the sides more curved, it is possible to click on a grid intersection at the sides of the grid and drag it towards the correct location. However, if the grid is large, this will be a time-consuming process. Instead, we select some points called NoMovePoints, which we will drag to the sides. Then straight lines will be made between these points.

From the menu, choose *Define* and *Set NoMovePoints mode*. Then click with the mouse on some of the grid line intersections on the left side of the grid (right bank). Each time a click is made, a *NoMovePoint* is made. These are indicated with blue squares. Make 6-7 *NoMovePoints* on the left side of the grid. Then choose on the menu *Define* and *Set NoMovePoints mode* again. This allows you to

click on the grid and move grid intersections without creating more *NoMovePoints*.

The next step is to move the *NoMovePoints* to the boundary of the river, given by the *geodata* points. This is done by clicking on a *NoMovePoint* and dragging it outwards to the blue *geodata* points. Figure 2.9.3 shows this, where one *NoMovePoint* has been dragged.

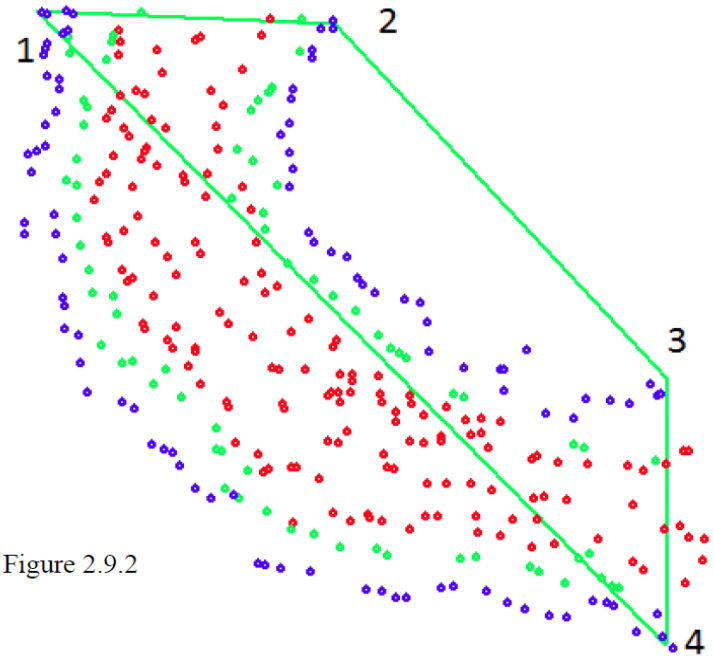


Figure 2.9.2

Next, repeat the dragging of the other *NoMovePoints* to the bank of the river. Then from the menu, choose *Generate* and *Boundary*. And then choose *Generate* and *TransfiniteI*. The grid is then moves along the outer bank of the river. Repeat the same procedure with the *NoMovePoints* on the inner side of the curve. Note that it may be an advantage to scale the figure in the window with the PgUp / PgDn buttons on the keyboard, and also use the arrow keys. If you make a mistake, and for example put a *NoMovePoint* in the interior of the grid, this can be removed with the menu option *Define* and *Delete NoMovePoint*. Then the last *NoMovePoint* is deleted.

From the menu, choose *Generate* and *Boundary*, and then *Generate* and *TransfiniteI*. You can also move individual *NoMovePoints* and repeat the *Boundary* and transfinite grid generation, until you are happy with the grid. At the end, you can choose *Generate* and *Elliptic*. This usually gives the best grid. Figure 2.9.4 shows an example of how the grid can look like.

The grid can then be saved to the *unstruc* file. This is done by the menu options *Generate* and *3D grid*, and then *File* and *Write unstruc file*.

The procedure so far has given the horizontal layout of the grid. The vertical extension of the grid also need to be decided. This is done by using the *geodata* points to determine the bed level of the grid by interpolation. The menu option is *Generate* and *bed levels*. After this, use the menu again with *Generate* and *3D Grid*. The grid should then be saved to the *unstruc* file again.

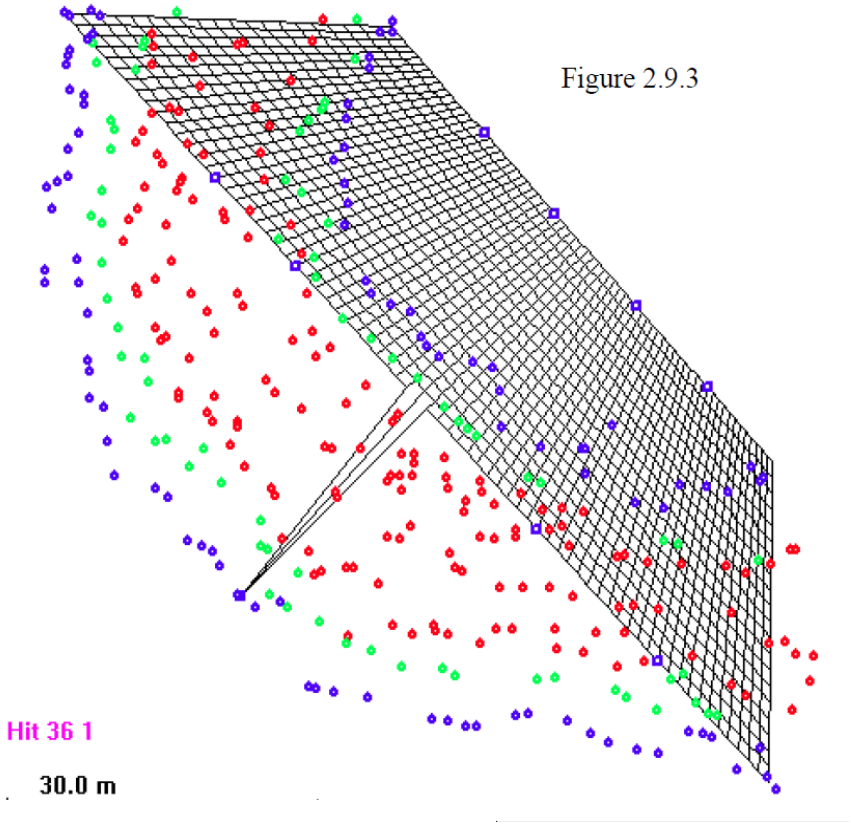


Figure 2.9.3

The grid we have made may not be optimal. If we end the SSIIM 2 program and restart it, and then read the *unstruc* file, we can see how it looks by choosing on the menu: *View* and *Map*. Choose on the menu *Variable* and *bed level*. Then on the menu choose *View* and *Legend*. Then the geometry may look like what is shown in Fig. 2.9.5. There may be holes or hills where the bed interpolation algorithm has not done a good job. Then it is possible to go back to the *Grid Editor* and give in the vertical level on individual grid intersections. Click on the grid intersection and from the menu choose *Define* and *Give coordinates*. Then give a better *z* value in the dialog box. Repeat this for all problem areas and then from the menu choose *Generate* and *3D Grid*, and then save the *unstruc* file. Do not generate new bed levels, as the algorithm with overwrite any manual changes to the coordinates.

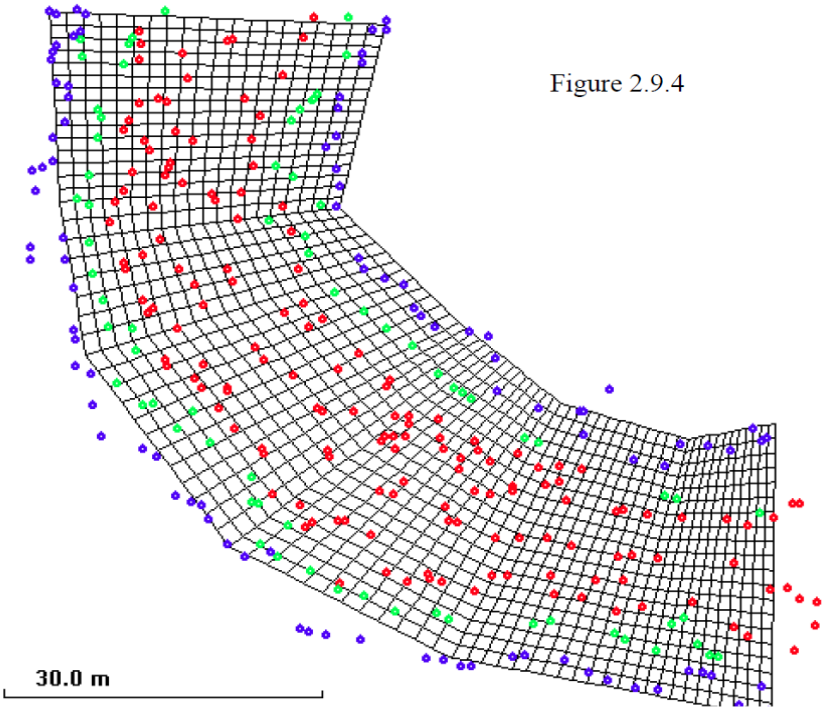


Figure 2.9.4

Note that it is also possible to improve the grid by adding or removing *geodata* points in the *Grid Editor*.

Step 2. Specifying a water discharge

The water discharge can be specified using the *Discharge Editor*, as described in the earlier tutorials. However, for a river where there is only one block and the water is flowing into one of the four sides and out of the opposite side, like we have in the current case, there is another option. This is to specify the following data sets in the *control* file:

F 314 1 1
F 237 1 1.5
F 237 2 1.5

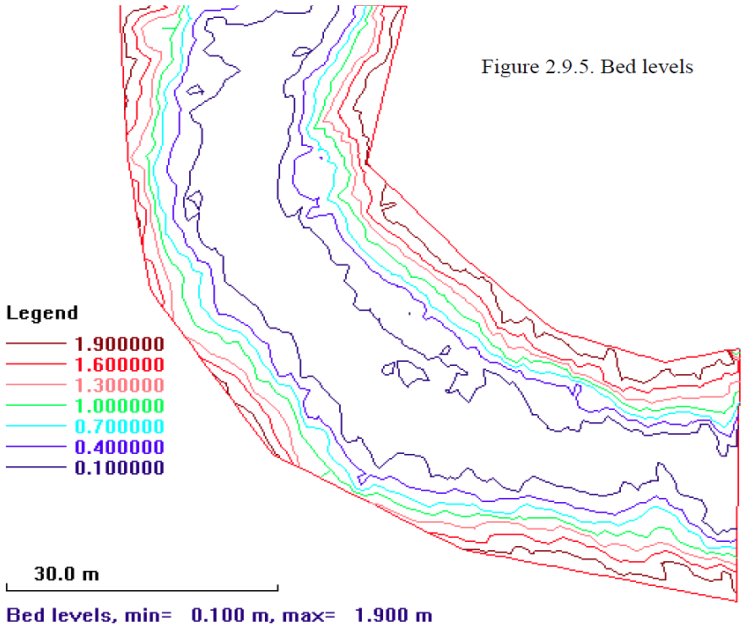


Figure 2.9.5. Bed levels

The *F 337* data sets specify the water discharge in m^3/s, while the *F 314* data set sets the grid ends to inflow and outflow.

If we open SSIIM 2 again, read the *unstruc* file and look in the *Discharge Editor*, we can see the coloured lines from the inflow and outflow. If we look in the dialog box, we see that the water discharge is the same as specified in the *control* file.

Step 3. Computing the water flow

Start SSIIM 2, read the *unstruc* file and from the menu choose *Compute* and *Waterflow*
Push the F10 button on the keyboard and watch the residuals decrease. When they are under 0.001, the solution is converged.

On the menu, choose *View* and *Map*, and then *Variable* and *Velocity vectors*. Scale the vectors with the F7 or F8 button on the keyboard until they look clear.

Step 4. Making an initial water surface

The top of the grid made in Step 1 is horizontal and at the level of the highest *geodata* point. This is at 2 meters with the current data. Often the geometrical points measured in the river include the overbanks. This makes sense when modeling a flood. However, if we want to model a lower water discharge, we also want a lower water level. The easiest way to lower the water level is by specifying surface points in the geometry. This is done by first reading the *unstruc* file, and then go to the *Grid Editor*. Then from the menu choose *Define* and *Set surfacepoint*. A dialog box emerges, asking for the level of the surface point. Normally, we choose three surface points, all outside the geometry of the grid. The three points will form a triangle with a defined surface. This will be the new surface.

Scale the grid down with the PgDn button on the keyboard and move it to the center of the window. Then click with the mouse outside the grid. Go back to the menu and repeat the procedure two more times. The three emerged surface points will form a triangle. The grid should be inside the triangle, as given in Fig. 2.9.6.

Then go to the menu option *Generate* and *Surface*, and then *Generate* and *3D Grid*. Then write the *unstruc* file. Also, you can look at the *Map* in the *View* menu, and choose *Water level* or *Depth* from the *Variable* menu option. You can see that the water surface elevation has been reduced to 1 meter. You can now recompute the water velocities with this water level.

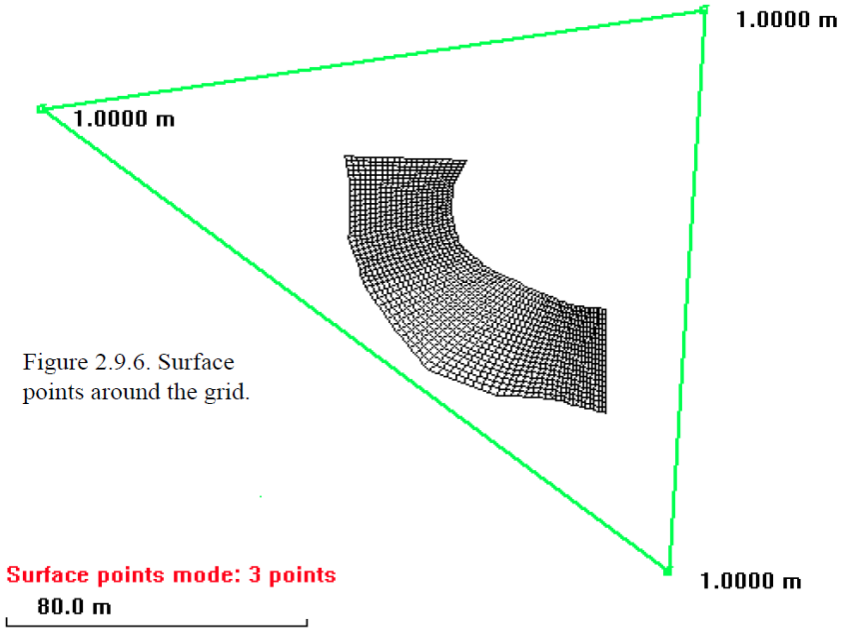


Figure 2.9.6. Surface points around the grid.

Note that you may choose a different level on each of the three surface points. Then a sloping water level is given.

Looking at the grid, the edges following the banks may not look too smooth. To improve the river bank cells, the *control* file needs to be modified. Open the file with an editor and add the data set *F 102 1*. Save the file, restart SSIIM 2, go to the *Grid Editor* and choose from the menu *Generate* and *3D Grid*. Go back to the *Map* view and see how the edges are smoother, similar to Fig. 2.9.7. Then save the *unstruc* file.

When you want to compute the water flow for this grid, the solution may not converge. This is because some of the grid cells will have a very low height to length ratio, or the area between the cells is very small. There are several methods to improve convergence. This is further described in Chapter 3.2. The methods involve using stabilizing procedures by adding data sets to the *control* file. The first thing to do is to lower the relaxation coefficients by adding a *K 3* data set. If that doesn't work one or more of the following additional data sets may be used:

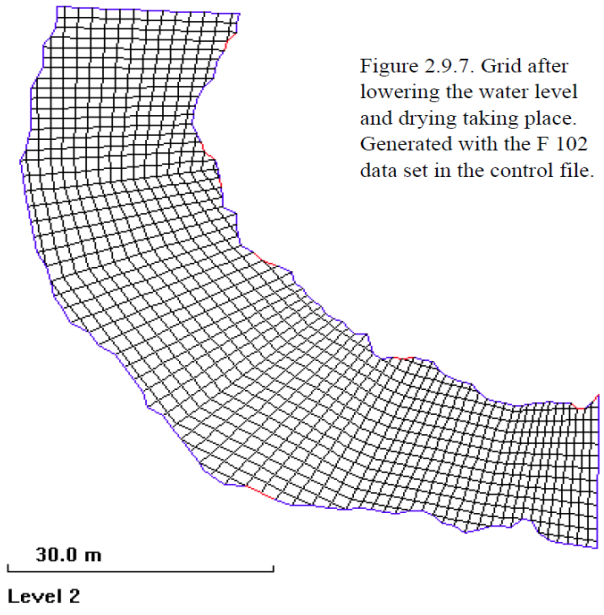


Figure 2.9.7. Grid after lowering the water level and drying taking place. Generated with the F 102 data set in the control file.

F 94 0.02 0.1 minimum cell corner heights
F 168 8 multi-block solver
F 159 1 9 0 1 0 disconnecting cells in shallow areas
F 235 10 triangular cell damping
F 292 0.1 inner time step
K 3 0.3 0.3 0.3 0.05 0.2 0.2 lowered relaxation coefficients
K 5 0 0 0 10 0 0 multi-block sover

The *F 94* and *F 159* data sets give parameters for generating the grid. This means the grid needs to be regenerated after this data set is given in the *control* file. The regeneration is done in the *Grid Editor*. Remember to save the *unstruc* file afterwards.

Step 5. Computing the water level more accurately

Although the chosen flat level of the water may correspond reasonably well to the real world, it may sometimes be necessary to make a more accurate model. There are several algorithms in SSIIM 2 for computing the water level. The most relevant ones for river modeling are based on approximately subcritical flow, where the downstream water level is specified. The user then has to specify a cell with a given water level, which is unaffected by the water surface computation. The reference cell must be specified on the *G 6* data set in the *control* file. The next step therefore involves which cell to choose and how to choose it.

On the menu, choose *View* and *Map*. Then choose *Variable* and *Cell numbers*. Enlarge the downstream part of the grid using the PgUp and the arrows buttons on the keyboard. You will see something like what is given in Fig. 2.9.8.

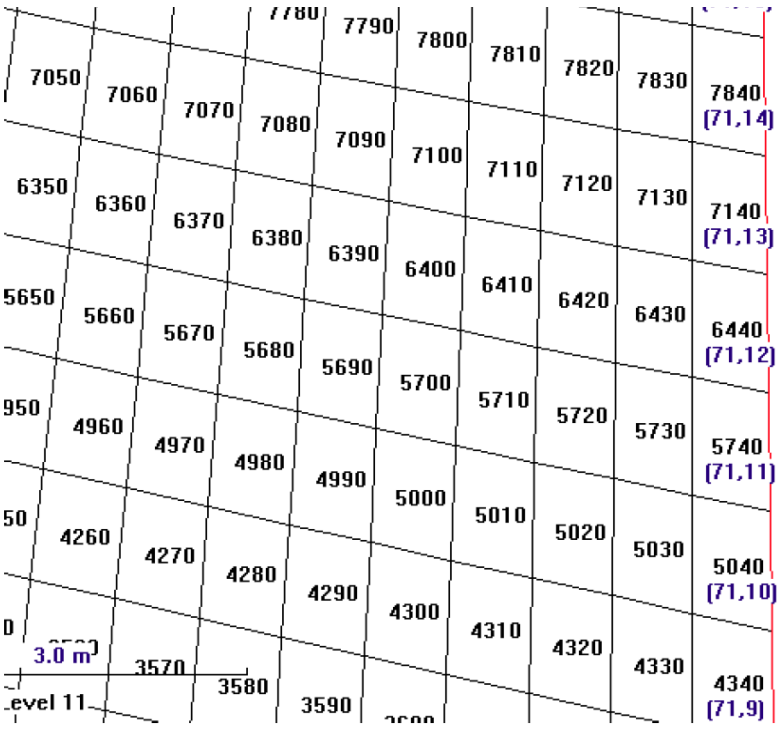


Figure 2.9.8

Cell numbers for the down-stream part of the grid

Push the F12 button on the keyboard repeatedly, until the numbers don't change any more. Then choose one of the numbers in the cell where the outflow is. Typically in the middle of the outflow region. For example 6440 in Fig. 2.9.8. Then give the following data set in the *control* file: *G 6 6440 0 0 0.01 0.1*

It is also necessary to specify a time step and which algorithm is to be used for the free water surface computation. To the *control* file, add

F 33 2.0 100
F 36 2

Then restart the program, read the *unstruc* file and start the water flow computations. In the Map graphics, look at how the water level changes. Note that the water level will only be updated if the residuals are fairly low. Lowering the time step or increasing the number of inner iterations on the *F 33* data set may be necessary to reduce the residuals.

2.9 Tutorial 7. Sand trap with experimental data (SSIIM 2)

This tutorial is based on the data from the laboratory experiment by Olsen and Skoglund (1994). The study modelled a laboratory sand trap where water velocities and sediment concentrations were measured. The geometry and measured data are taken from the web page: http://folk.ntnu.no/nilsol/cases/doris. (Doris is the name of the lab flume)

Step 1: Grid

To save download time, the *unstruc* file is not given on the web page. Instead, a *koosurf* file is given. The *unstruc* file is generated in the first step using the *koosurf* file. This can be done from the GridEditor, or it can be done automatically by modifying the *control* file. The *F 2* data set in the *control* file must then be: *F 2 YH test*. The *Y* letter invoke functions that read the koosurf file first, and then make the 3D grid. The *H* letter will invoke a function writing the *unstruc* file. Or the *control.g2* file from the web site can be used and renamed *control* without extension. After the *unstruc* file is made, SSIIM 2 must be terminated before next step. Note that a SSIIM 2 version made after June 2015 must be used.

Step 2: Water velocities

The next step is to compute the water velocities. Before this is done, the discharges need to be specified. This can be done in the *DischargeEditor*, or alternatively, by using the *F 314* and *F 237* data sets, as given in the *control* file from the web site. Edit the *control* file and replace the *YH* on the *F 2* data set with *UW*. Or use the *control.u2* file from the web site, renamed without extension. Then restart the program and wait until it converges. The measured water velocities are given in the *verify.u* file. This file was used in SSIIM 1 to compare measured and computed values directly in the SSIIM 1 graphics. It is actually better to use a spreadsheet for this comparision - the graphics will be better, with scales, legends etc. The verify file gives the velocities at profiles specified with (x,y) coordinates. This is the same coordinate system as used for making the grid. Comparing the computed and measured results, it is necessary to produce profiles of computed velocities at the same location as the measurements. This is done with the *interpol* file. A file called *interpol.u* is given on the web page. This can be downloaded and put in the working directory. It also has to be renamed *interpol*, without an extension. Then, the *control* file has to contain the data set *F 48 2*. When this data set and the *interpol* file is used and SSIIM 2 writes the results, SSIIM 2 will also produce a file called *interres*. This contains the computed velocity profiles at the locations from the *interpol* file. Which is the same as the measured profiles. The data from the *interres* file and the *verify.u* file can then be taken into a

spreadsheet and compared.

Step 3: Sediment concentrations

The third step is to compute the sediment concentrations. To do this, the *control* file has to be modified, or the *control.s2* file used. Add *F 37 2*, *F 33 10.0 10* and *F 68 2*. The *F 68 2* data set will invoke a computation where the water velocities are not recomputed for each time step, only the sediment concentrations. This will save computational time and not deteriorate the results as the bed elevation changes were very small. Also, replace *UW* on the *F 2* data set with *F 2 URSM*. The *M* invokes a function writing a new *interres* file. Also, change the *F 48* data set to *F 48 6* instead of *2,* which will produce concentrations instead of velocities. This time, we will use the *intepol.c* file, which can be downloaded and renamed interpol. Also, add an *F 1 D* data set in the *control* file. This will write the sediment fluxes to the boogie file, enabling computation of the trap efficiency for the sand trap. The first parameter on the *K 1* data set can be reduced to 100, to save computational time. This means only 100 time steps are used. A transient computation of the sediment concentration is done here, but over a long time so that a steady state is produced at the end of the computation. Also, the *timei* file from the web site has to be used.

Using the data for other CFD programs

If you want to compute the water flow and sediment concentration using another CFD program, it is possible to use the data from the current case. Most CFD programs will use a rectangular grid block which is modified using an STL file. The STL file of the current geometry can be written from SSIIM 2 and imported into the other CFD program.

2.10 Examples

Example cases with input files can be downloaded from the Internet, at one of the links from:

http://folk.ntnu.no/nilsol/ssiim

Some of the files are located in the package containing the OS/2 version of the program. This can be downloaded at: http://folk.ntnu.no/nilsol/ssiim/ssiimos2.zip. The input files for the OS/2 version and the Windows version are the same.

Some of the examples are explained in the following:

Water quality with Streeter-Phelps model (SSIIM 1)

The input files have extension *.qua*

The water quality in a river is modelled with the Streeter-Phelps model. This has two water quality constituents: Organic substance measured in Biological Oxygen Demand (BOD) and Oxygen Saturation Deficit (OSD). The convection-diffusion equation for each constituent is solved, including

source terms for biochemical reactions.

Start by calculating the water flow field using *MB-Flow2D* or *MB-Flow3D*. Afterwards, start the water quality calculation. You may use the calculation menu.

The OpenGL 2D graphics is well suited to show the results.

This case is used for testing the numerical model against an analytical solution.

Curved channel (SSIIM 1)

The files have extensions *.svi*. The channel is used for testing the programs ability to calculate the secondary flow pattern in a curved channel. It is also used for testing the routine that recalculates the water surface location based on the 3D flow field. The cross-sectional slope corresponds very well to theoretical solutions.

Fish farm tank (SSIIM 1)

The files have extensions *.kar*. This case is used for demonstrating inflow and outflow at different locations in the geometry. The inflow is on one side, at 45 degrees to the wall. The outflow is at the bottom of the tank. The case is also used for demonstration of fish habitat. It is also suited for particle animation because the particle will move in a circular pattern. This case is calculated by Olsen and Alfredsen (1994).

Reservoir trap efficiency (SSIIM 1)

The files have extension *.res*. This case is used for demonstration of trap efficiency calculation in a reservoir. It is a modified version of the Mae Tian reservoir calculation case from Thailand (Olsen, 1991 and Olsen and Melaaen, 1993). 8.3 cubic meters of water is flowing through the reservoir. Several sediment sizes are used. The user can see the contour map of the bed levels, colour map of the bed level changes, cross-section velocities and longitudinal profiles of the sediment concentration.

Note that about 9000 iterations are necessary to make the water flow calculation converge. This took about 2 hours on a Pentium Pro 200/512 k Cache, 32 MB RAM.

Flood wave hitting a building (SSIIM 1)

The files have extension .wav. This example shows a flood wave in a 50 m long and 25 meter wide channel hitting a square building with sides 5 meters. The upstream water surface is 3 meters above the bed, and a water velocity of 3 m/s is in the inflowing water. A transient free surface routine is used to calculated the water surface. The speed and the depth of the wave correspond well to hydraulic formulas. Forces on the building are written to the forcelog file. The case was presented by Olsen (1994). A similar verification study with comparison with a physical model testing was done by Loevoll et. al. (1995) and Lovoll (1996). The flood wave case was also discussed by Sintic (1996).

The *control* file includes *G 19* data sets to view the water surface with the 3D OpenGL graphics. This can be done while the computation is running.

Also note that the forces on the obstacle is written as a time series to the forcelog file.

Scour in a flume (SSIIM 1)

The files have extension .sco. This shows the scour in a flume where an obstruction is placed. To avoid excessive computational time for this case, a very coarse grid has been used. The grid is too coarse to resolve the flow field around the obstruction enough to simulate local scour. However, scour because of channel contraction is simulated. Except for the coarse grid, this case is similar to the local scour case presented by Olsen (1996).

The time step is chosen to be 1000 seconds. This is also to avoid excessive computation time when running the example. This allows the user to observe how the bed evolution changes. The time step is however to long to give an accurate prediction of the evolution of the scour.

Note the grid extends relatively far downstream of the obstacle. For some cases this has shown to be necessary to avoid unphysical results at the downstream boundary.

The development of the scour hole is best seen with the contour map graphics or the OpenGL graphics, showing the bed level seen from above. Note some bugs in the contour map graphics causes some lines not to be shown at all times.

Advice on scour computations

Local scour has been computed with SSIIM in several studies. The last one was Baranya et al (2013), where SSIIM 2 was used and a nested grid. The nested grid has the advantage that a fine grid can be used around the obstacle, while a coarse grid can be used to model the river. SSIIM 2 then has to be used. There is information about the nested grid in Chapter 3.8.

Bihs and Olsen (2011) investigated local scour and found that the most important parameter for determining the maximum scour hole depth was the reduction in the critical shear stress for erosion of a particle as a function of the bed slope. Several formulas were used. Different formulas can be specified on the *F 182* data set in the *control* file. Not using any of these formulas, grossly underpredicted the scour hole depth.

Also note that the *F 56* data set should be used to model the local slide at each bed cell, preventing too steep bed angles. It is recommended to use 200 as the first integer on the *F 56* data set, as this algorithm will give a round scour hole. Older algorithms are grid-dependent and will give “arrow”-shaped scour holes.

Chapter 3. Advice for using SSIIM

3.1 The grid

Making the grid is often the most time-consuming process in the preparation of input data for SSIIM or other CFD computations. The general idea is to divide the water body into cells. The size and alignment of the cells will strongly influence the accuracy of the calculation, the convergence and the computational time.

The grid used in SSIIM 2 is unstructured. This makes it easier to adapt the grid to complex geometries without loss of accuracy or slow convergence. In the following there are given some guidelines of how to make a good grid. Also, it is recommended to read Chapter 4.4 first.

Here is some advice on how to shape the cells:

1. Make the grid line intersections as perpendicular as possible. It is not advisable to have intersections with an angle of less than 45 degrees. Non-orthogonality in the grid will make the convergence slower. It is recommended to use the elliptic grid generator to make the grid smoother.

2. Try to align the grid lines in the streamwise direction parallel to the velocity vectors. This will decrease false diffusion.

3. The distortion ratio should not be too great. The distortion ratio is the dimension of the grid in one direction divided by the dimension in another direction. Some people say this should be less than 2 (two), but other people have obtained good results for ratios up to 10. On occasions, ratios of up to 100 have been used. This gave reasonable results, but it required very low relaxation coefficients and an extremely large number of iterations to converge.

4. The size of a grid cell should not be too much larger than its neighbours. Some people say the increase in size should not be greater than 20 %. On some occasions this value have been over 1000 % (a factor 10). Some of these cases gave reasonable results, but other cases gave unphysical results. A recommendation is to try to stay within 50 %, but if much larger values are used, be aware that unphysical results may occur. Unphysical results can be velocity vectors that point in another direction than what seems natural, for example not parallel to walls.

Chapter 3.2 give more advice on convergence and interpretation of the results.

3.2 Experience with convergence and stability

There are three ways SSIIM can crash:

1. The program stops calculation and there is an error message in the program window.
2. The program stops and exits, the menu and the dialog box disappear.
3. The program stops with a system error, usually floating point invalid operation, overflow or underflow error.

Often an error message is written to the boogie file before the crash occur. This happens particularly for type 1 and 2 of this list above. If an error in the input files are detected, an error message is written to the boogie file and type 2 crash occurs. If the program crashes, it is therefore recommended to take a look at the boogie file. If crash type 1 occurs, it is also possible to look at the graphics to try to see where in the geometry the problem is.

Convergence

If the program does not crash, the next problem is to get a converged solution. This is often a problem for many CFD cases. Some of the important factors are:

- A good grid
- Proper relaxation coefficients
- Correct boundary conditions
- A fast solver
- Stable numerical algorithms

It is always a good thing to check the boundary conditions in case of slow convergence or strange results. Also note that warning messages may be written to the boogie file if particular undesirable configurations are present. Therefore, check the boogie file if problems occur.

Experience shows that the degree of non-orthogonality of the grid will affect the convergence. A higher degree of non-orthogonality will give slower convergence. A slower convergence will also be experienced where strong gradients are present. This applies for example at the inflow of a jet from a wall.

The convergence speed is strongly influenced by the choice of the solver. For most cases, using block-correction (*K 5* in the *control* file for SSIIM 1) will lead to much faster convergence. A speed-up of one order of magnitude has been observed for some cases. SSIIM 1 has reasonably good block-correction algorithms. The block-corrections in an unstructured grid like for SSIIM 2 is more problematic, but a multi-grid algorithm is implemented for use in shallow flows (*F 168* and *K 5 0 0 0 10 0 0* in the *control* file).

For most cases lower relaxation coefficients will give less instabilities during the convergence, but a slower convergence. Higher relaxation coefficients will give more rapid convergence if there are no instabilities. This is however not always the case. Instabilities can be observed during the iterations when the residual or the velocities increase and decrease periodically. But for most cases of instability

problem it is recommended to lower the values on the *K 3* data set in the *control* file. The default values are 0.8 0.8 0.8 0.2 0.5 0.5. The first lowering may be to *K 3 0.4 0.4 0.4 0.1 0.2 0.2*. If the instabilities are still there, it is possible to try *K 3 0.2 0.2 0.2 0.05 0.1 0.1*, for example.

For a few rare cases with SSIIM 1 and steady computations, where the equation for k is slowest in convergence, a more rapid convergence has been achieved when changing the relaxation coefficient for the turbulent kinetic energy, *k,* from 0.5 to 1.0 after several iterations. However, for most cases this procedure will not work.

For the convergence of the *k* and epsilon equations for river problems, the size of the cell closest to the bed is important. In SSIIM 1, this can be changed by changing the second number in the G 3 data set in the *control* file. This parameter also depends on the roughness of the bed. The height of the bed cell should not be too much smaller than the roughness of the bed. The following formula is used to determine the roughness of the bed, given the Stricklers friction coefficient *n* (van Rijn, 1982):

$$n=\frac{d_{90}^{1/6}}{26} \quad \text{and} \quad k_s=3\,d_{90} \tag{3.2.1}$$

If the solution blows up after the first few iterations, it is possible to set the relaxation coefficients very low, and then increase the coefficients for the following iterations.

For some cases there have been problems getting the solution to converge if there are parts of the geometry that has relatively low total velocity. Experience has shown that the initial conditions then may be important. If such a situation is present it is important to start the iterations with very low initial velocities. This is done with the *G 8* data sets.

An advantage with SSIIM compared with other CFD programs is that the graphics is connected directly with the computational module. This enables the user to see the results while the program is doing the computations. If problems occur, it is recommended that the user look at the graphics to try to identify these. This would be similar to a physical model study, where the engineer will watch what happens during the run. Looking at velocity vectors, pressure fields, bed level changes and the location of the water surface gives an idea about reasons for crashes.

For convergence problems, SSIIM 2 has an option of showing plan view of the residuals in 2D. This makes it easier to identify areas of high residuals.

Transient calculations

If during steady calculations there are oscillations in the velocities, this may be a sign that the flow field has a transient character. One may then invoke the transient calculation and a periodical transient solution may be observed. However, another possibility is that the oscillations disappear after adding transient terms. The transient terms can have a stabilizing effect on the solution for some cases.

Note that a steady state solution may very well emerge even though the corresponding prototype flow field has transient oscillations (Olsen and Melaaen, 1996). The reason for this is usually that the turbulence model overpredicts the eddy-viscosity, or the grid is so coarse that false diffusion dampen

out the eddies.

For very large grids (over 50 million cells) an experience with SSIIM 2 is that a time step is needed initially to stabilize the solution. However, after some time the decrease in the residuals will be very low. A faster convergence has then been achieved if the result file is first written and then the computations are restarted without the time step, but by first reading the result file.

Convergence problems with shallow/triangular cells during wetting/drying computations

Transient computations with wetting/drying sometimes give convergence problems and crashes at the boundary of the geometry. This situation can be identified when looking at the *Map Graphics*, where large velocity vectors are observed after a crash. During computations, the *Map Graphics* may show very high residuals at the side boundary. Also, the velocity vectors may seem to oscillate there before the crash. This is typically taking place in triangular cells or very shallow ares, often at a flow separation point on the side boundary. It is recommended to look at the velocity vectors in the graphics when oscillations occur. Then problems may be more easily identified.

Sometimes the problem is due to low depth/roughness ratios. In the *Map Graphics*, it is possible to see this ratio directly. If the ratio is low, then the wall laws (Eq. 6.1.16) can give negative U+ values. This will cause instability and crashes.

Advice for solving instability issuses is to introduce stabilization algorithms by adding data sets to the *control* file:

1. Lower the relaxation coefficients on the *K 3* data set

2. Introduce an inner time step with the *F 292* data set in the *control* file. For example *F 292 1 1.0*, where 1.0 is the inner time step in seconds. The inner time step should be chosen much smaller than the time step on the *F 33* data set. The inner time step will only contain information about the flow field from the last iteration, and not from the previous time step. Therefore, the inner time step will act more like a relaxation factor, and dampen changes between each inner iteration.

3. If the instabilities are due to low depth/roughness ratios, the minimum depth on the *F 94* data set can be increased. This an effective measure to dampen instabilities due to oscillations. The reason for these type of instabilities is most often an extreme length/height ratio of the cells. If an *F 94* data set is already used, then the numbers should be increased. If the *F 94* set is not used, then look in the *boogie* file to see what the default values are. Then introduce an *F 94* data set with higher values. The disadvantage of using higher values on the *F 94* data set is that the most shallow areas of the geometry will not be modelled, or modelled with only one cell in the vertical direction. An alternative/additional option is to increase the minimum *U+* value. This is set on the *F 139* data set. The default value is 1.0. This can be increased to for example 3 or 4.

4. Use the *F 159 d*ata set to change some of the grid generation methods. For example, the second parameter can be changed to 9, removing ridges in the grid.

5. Sometimes a combination of unfortunate pressure/velocities may cause a crash. If the *F 219* option is invoked, the program will set the pressure to zero and start over again in the current time step when the

residual reaches 10^8. A warning message is then written to the *boogie* file. This is called a flushing of the pressure field.

Grid splitting

This instability may occur when using a free surface algorithm in shallow areas. The water surface changes are so large that a complete area between the inflow and outflow disappears. The grid is then split in two, with no connection between the parts. This is both numerically incorrect and an unphysical situation.

The situation will most often occur when using *F 36 2* or *7*. The first thing to do then is to lower the relaxation coefficient for the water level movements on the *G 6* data set. The two last numbers on the *G 6* data set are floats, the relaxation coefficient is the first of these. The coefficient can be lowered to 0.01 from the default value of 0.1 However, the water level will then also sink more slowly, so it should be checked if this cause a problem. If so, then the time step has to be lowered.

An alternative solution for the problem is to use an implicit Shallow-Water Equations solver to compute the changes in the water levels. This is usually more stable than methods based on the pressure from the Navier-Stokes equations. Then, *F 36 9* is used in combination with *F 323 1*.

Algorithms to improve the convergence of the *F 36 9* options can be given on the *F 343* data set. *F 343 3* invokes a classical multigrid method, while *F 343 2* invokes a block-correction method in 1D in the streamwise direction of the geometry.

A new algorithm to prevent grid-splitting was made in 2016. This is invoked by *F 271 62 0 0*. The algorithm was further improved in 2018, then with the additional parameter *F 408 1*. The algorithm tries to make a wetted path in the 2D grid, following the main flow. This path is not allowed to dry up. The *F 408 1* algorithm expands the path laterally, so it may cover more than one cell.

3.3 Interpretation of results

As mentioned earlier, it is advisable to have experience in computational fluid dynamics when proper interpretation of the results is required. Some guidance is given below.

An important numerical effect that can deteriorate the results is false diffusion. This effect is most noticed for first-order schemes, including the POW scheme. However, also high-order schemes introduce false diffusion, although less than the first order schemes. False diffusion depends on how well the flow velocity vectors are aligned with the grid lines. For small alignment angles, the effect is small. Maximum false diffusion will happen when the grid lines are aligned 45 degrees with the flow. The amount of false diffusion also depends on the size of the grid cells.

There are three methods to decrease the amount of false diffusion:

1. Decrease the size of the grid cells = increase the number of cells

2. Align the grid with the flow field
3. Use a high order scheme

Point 2 may be difficult in a practical situation. However, the calculations should be carried out using approach 1 and/or 3 to assess the effect of false diffusion.

Another important aspect is the boundary condition. This especially applies to the inflowing boundary. If the velocity field at the inflowing boundary is not known exactly, one should try different velocity distributions to try to assess the effect of this parameter. For a river running into a reservoir, it is possible to model a part of the river upstream of the reservoir, and thereby obtaining a better estimate for the velocity distribution where the river enters the reservoir. The upstream boundary condition is also important for sediment calculations, where both the total amount of sediment inflow and the sediment grain size distribution can be varied. For the bed boundary, it is possible to vary the roughness to investigate the effect of this parameter. It can also sometimes be advantageous to make variations for the formula for sediment concentration close to the bed. This especially applies for sediment particles outside the range for which the formula is applied for.

When interpreting the results from the model it is also important to keep the accuracy of model in mind. The k-ε turbulence model has limitations in how accurate the turbulence field is predicted. This will also affect the velocity field. For example, when calculating the recirculation zone for a step case, the length of the recirculation zone can often not be predicted with any better accuracy than 10-30 %.

In some situations the water flow will be time-dependent. An example can be oscillations behind a cylinder or in an expansion. It is possible to obtain a converged steady solution from the model although the physical problem is unsteady (Olsen and Melaaen, 1993 and 1996). This must be considered when interpreting the results. The effects of an unsteady solution compared to the given solution should be assessed if this is probable. When an unsteady case is solved with a steady method there can be convergence problems. If the relaxation factors have to be fairly low to get the solution to converge, this can be an indication that the flow field may be unsteady.

Another topic of interpretation is the resolution of the calculated flow field compared with the size of the grid cells. Several cells are required to dissolve a recirculating zone. Flow field characteristics smaller than about 4-7 cells may not show up in the solution. And a recirculation zone with very few cells may be inaccurately calculated because a certain resolution is required.

For some flow geometries the Navier-Stokes equations may have more than one solution. This can for example be seen in a flume with a symmetric expanding channel, where the jet may follow one side of the channel. If an obstacle is inserted into the side with the jet, the jet moves to the other side of the channel. This phenomena have also been experienced in non- symmetrical expansions, when varying the number of grid cells caused the Navier-Stokes equations to converge with a completely different flow field. It is thought that this problem has a higher risk of occurrence in geometries with expansions and recirculation zones, and also if the Second-Order Upwind scheme is used instead of the Power-Law Scheme.

Transient sediment computations

Over the last years SSIIM has been used for several cases with transient sediment computations. The

bed then changes over time in a geomorphological simulation. Some experiences have been obtained, given in the following.

In current SSIIM versions, the sediment transport boundary condition for the bed is based on van Rijn's formula. This formula is developed for fine uniform sediments in a flow with relatively low water velocity and great depth. It is not certain that the formula will produce good results for other cases. However, it may do so. It is important to assess the results by comparisons with laboratory experiments or field data. In van Rijn's formula, one parameter is the distance from the bed. In SSIIM, this is chosen to be half the height of the cell closest to the bed. This means it may be possible to obtain different results for the sediment transport depending on the magnitude of the cell closest to the bed. It is therefore advisable to include this variable in a parameter sensitivity test. An algorithm is included in SSIIM to take into account unusual values of the ratio of

$$a/b$$

where a is the distance from the bed and b is the bed form height. The algorithm is based on the Hunter-Rouse distribution of suspended sediments. It is invoked by using the *F 60 / F 110* data sets.

Doing a sediment computation, it is important to use the correct shear stress at the bed. The shear stress is a function of the bed roughness. There are several options on how this is computed, and it is recommended to use a reasonable value. It is possible to let SSIIM compute the effective roughness as a function of the sediment grain size distribution and the bed form height. This is of course the most elegant solution. However, the bed form roughness is computed by van Rijn's method, which may not give accurate results for all cases. The method is derived from uniform grain size data, giving higher bed forms than less uniform bed grain size distributions. The default roughness in SSIIM is 2 cm, which should not be used unless this is a reasonable value. Determination of the roughness algorithm is done on the *F 90* data set.

The numerical algorithms are approximations to exact formulas. The accuracy may therefore be variable. It is recommended to check the sediment continuity when doing sedimentation computation. This can be done by using the *F 1 D* option in the *control* file. Sediment continuity fluxes are then written to the boogie file for each iteration. One common reason for sediment disappearing is that the solution of the equations for the sediment grain size distribution has not converged. This is particularly the case for multiple sediment sizes. The convergence criteria and number of iterations for the solver is given on the *F 4* data set. It is recommended to try to lower the convergence criteria and increase the numbers of iterations if there are sediment continuity problems. This will, however, lead to increased computational time, especially if there are many sediment sizes.

Transient sediment computations are often done in connection with a moving free surface. This may lead to stability problems. One reason may be that the water level is only updated each 10th iteration (default). The water depth may then change a lot, and supercritical flow may occur in some locations. The problem may be solved by reducing the time step or decrease the number of iterations between each water surface update. This is done on the *F 105* data set.

When wetting/drying occur, some part of the water body may form ponds in the grid, separate from the main flow. If the ponds do not have an inflow or outflow, the coefficients in the discretized equations will be zero. This may lead to a situation with division on a very low number, close to zero, and

instabilities may result. An algorithm to avoid the problem can invoked by *F 104* data set. The number given on the data set is added to the a_p term for the cells that have low a_p values. Another option is to use the *F 394 10* data set, which removes ponds from the grid.

The accuracy of the computation is often a function of the number of grid cells. For the vertical direction, this can be controlled by the *F 87* data set. It is recommended to change the grid resolution to see how this affects the results.

Another empirical parameter is the minimum grid cell size. This is given on the *F 94* data set. Experience from the Kali Gandaki reservoir flushing case showed that values of 1 cm worked well when modelling a physical model with water depths of around 5 cm. The horizontal sizes of the grid cells were 10-30 cm for this case.

3.4 Common problems

By own experience and watching students using SSIIM, there are some frequent problems that can occur.

Sequence of actions

In some examples, the *F 2* option is given is given in the *control* file, so that the computations starts automatically. It is most often not a good idea to read input files or start new computations while the program is computing something. This can easily cause the program to crash. If using the menu to start computations, make sure the grid is read completely before starting for example water flow computations. And make sure the water flow computations are finished before the sediment computations are done.

SSIIM 2 inflow/outflow specification

In SSIIM 1 it is possible to specify two or more in- or outflow regions vertically above each other using the *G 7* data sets. In SSIIM 2, the inflow and outflow are specified graphically in the *DishargeEditor*. A similar specification as in SSIIM 1 can be done by giving in the vertical levels in the dialog box where the discharge is given. The default value of the maximum level is set equal to the maximum number of grid cells in the vertical direction.

Say you have a case where the maximum number of levels was for example 11, and you specified an inflow discharge between level 1 and 11 and this was stored in the *unstruc* file. If the inflow/outflow region was in a shallow area, and only 1 cell over the depth was generated, this would still work. However, if you later increased the maximum number of grid cells to 20 in the *control* file, then the specification of 1-11 cells in the *unstruc* file would be incorrect. You would actually then only specify an inflow in the lower half of the geometry. If the inflow/outflow region was in a shallow are, only the top cell (no. 20) might exist. This meant that the inflow/outflow region would not exist and a there would be an error in the water continuity. So the advice is to be careful every time you change the number of grid vertical grid cells for SSIIM 2, and make sure the inflow/outflow data in the *unstruc* file

are changed accordingly. If you have inflow/outflow over the whole depth, give a large integer in the "to" field of the discharge editor dialog box.

It can also be useful to test that the inflow/outflow areas are correctly defined by checking the Discharge Editor while the program is running.

Problems with *unstruc* files made by program versions before summer 2012.

When the grid is made and the *unstruc* file is written, it may not look correct when it is read back in again. Typically, some of the grid lines along the boundary will move to incorrect coordinates. The reason for the problem lies in the way the geometry data is organized for the wetting and drying computation. To make it possible for lateral erosion to take place, the wetting procedure must have information about where the grid cells should be located outside the original river. To do this, the initial grid has to cover also the dry areas. This is done by using a high water level when making the initial grid and *unstruc* file. The water level should then be higher than all points in the bed, so that the grid will look structured when generated. The unstruc file generated with this water level has always to be used later when starting the program. To start the program with the correct, lower water level, this lower water level has to be given in the *koordina* file, together with the *F 112 1* data set. However, if a new *unstruc* file is written after the program is started with a lower water level, this will not contain the information about the grid in the dry areas. The strange lines will therefore appear when such an unstruc file is read.

This problem was corrected summer 2012, when also the *x* and *y* coordinates for the dry areas were written to the *unstruc* file. However, using *unstruc* files made before this time, the problem may still occur.

3.5 Bugs and bug finding

Sometimes SSIIM will crash or give strange results. This can be due to bugs. It can be difficult to find bugs in computer programs with 100 000 lines of code. However, the approximate location of a bug can often be found without any access to the source code. Some guidelines are given in the following that will be helpful in finding the bug.

1. Is the bug reproducible? How is the bug reproduced?

2. Is the bug only in the latest version of the program or also in older versions?

3. Are there any warning or error messages in the boogie file?

4. Is the bug connected with any input files? If you try different input files, or omit some input files, will the bug still be there? This applies especially to *bedres* files.

5. If the program ran well on an earlier case or a similar other case, what is the difference between this case and the current case?

6. Often, a bug can be related to one of the algorithms invoked by the data sets in the *control* file. By removing some of the data sets in the file, it may be possible to connect the bug to a specific data set. Or a combination of data sets and input files.

Complex bugs

A bug can show up right away after the program starts or it can emerge after long computational times. A bug that shows up right away is usually easy to find by debugging the source code. A bug causing incorrect results after a longer computational time is more difficult to find. This can be called a complex bug. Here are some advice in how to find such a bug:

1. Similar to a physical laboratory model, you can look at the physics of the problem, observed in the SSIIM graphics during the computation: Is the water surface location correct? Is the water depth correct? Is the velocity field correct? Are the secondary currents correct? Is the roughness correct? Is the shear stress correct and follow patterns of depth/velocity/roughness? Does the sediment concentration and bed changes follow the pattern of the shear stress? Is there enough sediments on the bed for erosion to take place? The thickness of the sediments is seen in the *Map* graphics.

For example, if the erosion is too deep, this can be due to a too small sediment size, to little inflowing sediments or too high shear stress. The too high shear stress can be due to too high velocities or too high roughness. If the velocity is too high, this can be due to too low water depth. Too low water depth can be due to too low pressure. By following the parameters in the graphics, it is often possible to trace the bug to an algorithm for specific physical process. SSIIM often has several algorithms for the same process, for example computation of the water level. Then other alternative algorithms for the same process can be tested.

During this testing, it can be useful to make ParaView or Tecplot animations of a number of variables, for example velocities, pressure, water levels, bed levels, bed changes, roughness etc.

For sediment computations, it is useful to look at the sediment continuity. The *boogie* file will provide more detailed results if *F 1 D* is given in the *control* file.

2. If the bug is in a complex case/geometry, it can be easier to find the bug in a simpler similar case. A typical simpler case is a straight channel with constant depth and velocity. Then, parameters as shear stress, sediment transport capacity and bed changes can be computed by hand and compared with the results from SSIIM. Another simplification is to use one sediment size instead of many.

3. It is often necessary to rerun SSIIM several times with different input parameters to find the bug. Considerable time can then be saved by using a coarse grid instead of a fine grid for the same case. It doesn't matter that the coarse grid will not give accurate results, as long as the bug is reproduced. It has happened that a bug was discovered after 6 weeks of computational time on a grid with 4 million cells. If a grid with 4000 cells had been used instead and the other parameters were the same, the bug had been found after a computational time of 1 hour.

3.6 Frequently asked questions

1. The program crashes. What do I do?

See Chapter 3.2

2. I think there is a bug in the program. What do I do?

See Chapter 3.5

3. How is the roughness specified in SSIIM?

Roughness parameters are needed for SSIIM for two purposes:

1. Generation of the initial water surface elevation (SSIIM 1)
2. Computation of the shear stress at the boundaries, through the wall laws

For point 1, the Manning-Strickler value of the *W 1* data set is used. This data set has to be given by the user. It is also possible to vary the value in different cross-sections by using the *W 5* data set. None of the other roughness options will affect the initial water surface location.

The shear stress at the boundary is computed using a wall law for rough boundaries. This wall law includes a roughness value in meters. One roughness value is used for all the side walls. This is called *XksWall* internally in the program. For the bed, a separate value is given for each cell in the two-dimensional array called *Xks[i][j]* in the computer program.

The default values of the roughness variables are given by converting the Manning-Strickler value of the *W 1* data set to a roughness height.

The user can override this value by using the *F 16* data set. Then both *XksWall* and *Xks[i][j]* will take this value. If the user wants to specify a spatially varying roughness at the bed, this can be done by making a *bedrough* file. Then only the *Xks[i][j]* values will be affected, and not the *XksWall* value. The roughness specified in the *bedrough* file will override the value specified on the *F 16* data set. This means that using both a *bedrough* file and the *F 16* data set, the value on the *F 16* data set will only be used for the side walls.

The roughness given in the *XksWall* and *Xks[i][j]* variables will not affect the location of the initial water surface. However, the variables will affect the shear stress and thereby the pressure in the flow field. So if the algorithm is used where the water surface is updated as a function of the pressure field, the water surface will be affected by the roughness values.

In the time-dependent sediment computations, invoked by using the *F 37* data set, it is possible to further change the roughness values in the *Xks[i][j]* array. This is done by using the *F 90* data set. Then the bed form height can be computed, and thereby also the bed roughness. This will again affect the location of the water surface if it is recomputed during the computation.

If you are unsure about what the roughness is for a given configuration of input, it is recommended to start the program and look at the roughness parameter in the Map graphics.

4. How is the free surface computed?

The free surface is computed using a fixed-lid approach, with zero gradients for all variables. The location of the fixed lid and its movement as a function of time and the water flow field can be computed by one of four different algorithms:

1. 1D backwater computation
2. Gravity and control volume algorithm
3. Pressure and Bernoulli algorithm
4. Shallow water equations

1D Backwater computation

The first algorithm is a 1D backwater computation. This computation is done when the program starts, and it is invoked automatically. It is a part of the grid generation for SSIIM 1. It is not used for SSIIM 2, which has a horizontal free surface as initial default. The initially generated free surface is used for the subsequent computations as a fixed lid with zero gradients for all variables, if no other free surface algorithms are specified.

Gravity and control volume algorithm (CGA)

This algorithm is used to compute the movement of the free surface. It is invoked by using the F 36 1 option. The algorithm includes the gravity term in the Navier-Stokes equations. A time step has to be specified by the F 33 data set. The basis of the algorithm is to use the continuity equation instead of the SIMPLE algorithm to compute the changes in the water surface. The algorithm is very unstable, and a very short time step has to be used for stability reasons. This algorithm is only used for cases with very steep water surface gradients, for example computation of coefficient of discharge for a spillway or a flood wave with a steep front.

In 2009, this algorithm was improved a bit for the SSIIM 2 version, giving a more stable solution. The new algorithm is invoked by *F 36 15* and called CGA (Continuity and Gravity on an Adaptive grid).

Pressure and Bernoulli algorithm

This algorithm is implemented in both SSIIM 1 and 2. It can be used for both steady and unsteady computations. The algorithm is based on the computed pressure field. It uses the Bernoulli equation along the water surface to compute the water surface location, based on one fixed point that does not move. The location of this point is given on the *G 6* data set, both for steady and unsteady computations.

For a steady computation, the algorithm is invoked by using a small number for the second integer on the *K 1* data set. This integer gives the number of iterations between each time the water surface is updated. For an unsteady computation, *F 36 2* is specified in the *control* file, together with the time step on the F 33 data set. Using this algorithm, it is possible to use the *timei* file to compute a location

of the water surface that varies over time.

The algorithm is fairly stable, so that it can also be used in connection with computation of sediment transport and bed changes.

The algorithms have been further developed in SSIIM 2, and the newest version, IPDA (Implicit Pressure Difference with Adaptive grid) is invoked with the *F 36 7* option. Further details are given by Olsen (2015).

Diffusive wave equations (IDWA)

This algorithms is only implemented in SSIIM 2. It is used similar to the Pressure and Bernoulli algorithm, but the *F 36 9* is specified in the *control* file, together with *F 323 1*. The method is more stable than the pressure and Bernoulli algorithm, but probably not as accurate for complex water surfaces. However, if the water surface is close to horizontal, which it usually is, then the accuracy may be of sufficient quality. Further details are given by Olsen (2015).

5. How can I convert between sediment fluxes, bed elevation changes and concentrations?

The concentrations in SSIIM is given as volume fractions, as in van Rijns formulas. That is the volume of the sediment particles as a fraction of the total volume of the water/sediment mixture. If the density of the sediments is 2.65 kg/litre, the mass fraction will be 2.65 times higher than the volume fraction. Or in other words, if you have a mass concentration, you need to divide by 2.65 to get it in volume concentrations. Note that concentrations in ppm are often mass concentrations.

The specific density of the sediments can be modified on the *F 11* data set in the *control* file, if you want a different specific density than 2.65.

A flux, F, of sediments in kg/s is obtained by the following formula: $F = c \rho_s U A$

U is the water velocity in m/s normal to the area A in m^2. The sediment concentration in volume fractions is c and ρ_s is the density of sediments in kg/m^3, for example 2650 kg/m^3.

In SSIIM 1, the inflow of sediments can be specified on the *I* data sets in the *control* file, in kg/s. They can also be specified for example in the *timei* file as a concentration. If a concentration is to be given, then this is the volume fraction. How this is computed is most easily shown in an example:

Let us say we have a water inflow of 3 m^3/s and a sediment inflow of 0.1 kg/s. The sediments will take up a volume of 0.1 kg / 2.65 kg/l = 0.03777 litres. The 3 m^3/s of water will take up a volume of 3000 litres The volume fraction will then be 0.03777 litres / 3000 litres = 1.25x10-5
The concentration value in the *timei* file should be 1.25e-5 or 0.0000125.

The next question is how much volume on the bed does a given amount of sediment take up? The default sediment packing on the bed for SSIIM is 0.5, meaning that 50 % is sediment particles and 50 % is water. This can be changed on the F 26 data set. One cubic meter of sediments on the bed therefore contains 0.5 m^3 sediments. This will have a dry mass of

0.5 m3 x 2650 kg/m3 = 1320 kg.

Of course, if the mass is wet, then the 500 kg of water must also be added, giving 1820 kg.

6. How do I specify an initial grain size distribution on the bed in SSIIM 2?

A spatial variation of the initial bed grain size distribution is done most effectively with the *fracres* file. The file gives the layer thickness and grain size distribution of each bed cell. The values for each cell is given on one line. The line starts with two integers, giving the 2D indexes for the cell. An indication about the index for each cell can be seen in the grid editor or the discharge editor, by choosing *View->legend* in the menu. This will give the index for the grid intersections. The corresponding cell will be in the direction of lower index values.

After the two indexes, then 2 x (1 + *n*) floats are read, where *n* is the number of sediment fractions. First, the thickness of the active, top layer is given. Then *n* fractions are read. Then the thickness of the inactive layer is given, and then n fractions are read for this layer.

The file can be made by using a spreadsheet.

Note that the order of the bed cells in the *fracres* file is not important. Also note that the values for the same cell can be given multiple times. Then it is only the last value that will be used. This "feature" can be useful when regions of different sediments are to be described. Then the whole geometry can be covered in one particle distribution, and then the region of different distribution can be given afterwards. It is not necessary to remove the originally given values before adding new ones. This can be nested as many times as necessary. The only limitation is the length of the *fracres* file, which must have less lines than 20 x the number of bed cells. If this is a problem, it is easy to increase the number and recompile the program.

After the *fracres* file is made, the user should read it and look at the grain size distribution and the sediment thickness in the SSIIM graphics. Then possible mistakes can be seen.

The *fracres* file specifies the thickness of each sediment layer, and thereby also the thickness of the total amount of sediments on the bed. This information is also given by the difference between the actual bed level and the limit of movable bed given in the *koomin* file. If the two ways of specifying the sediment thickness differ, then the input is undefined. In SSIIM 2, the *F 310* data set modifies the values from the *koomin* file or the *fracres* file to give correspondence.

The grain size distribution on the bed is also given in the *bedres* file, which can be used to initiate values from an earlier run. The *bedres* file is written from SSIIM 2.

Note that the *F 306 1* data set must be given for the sediment information from the bedres file to be used. Also *F 306 1* have to be given for the *fracres* file to be read.

It is useful to look in the SSIIM graphics after startup of the program to see if you have the initial values of the sediment parameters you want.

7. I get problems with generating the grid in SSIIM 2 when wetting/drying occurs.

See Chapter 3.4.

3.7 Lateral grid movements

This chapter describes the method to make a dynamic grid that can move in the lateral direction. Such a grid is used to model the wetting and drying process taking place in a meandering channel, or when modeling reservoir flushing. Note that this can only be done using SSIIM version 2, as an unstructured grid is necessary.

Some details of the grid generation algorithms are described by Olsen (2003). The general principle is to first generate a 2D depth-averaged grid over all the areas where the river may flow. This is done by using a water level that is higher than the bed everywhere. This 2D grid is then used as a basis for the 3D grid that is used to compute the water and sediment flow. The 2D grid stores information about the bed level location and sediment data. Also read Chapter 4.?.?, where more information is given.

The initial grid have to be given in an *unstruc* file, which is used when starting the program. This *unstruc* file can be generated in different ways, depending on the geometry. For a complex natural geometry, the *Grid Editor* in SSIIM 2 can be used, with input from a *geodata* file. This is described previously in this manual. Note that a high water level has to be used, that covers both the wetted and dry areas. The second method to generate the *unstruc* file can be used if a regular geometry is to be modelled. Then a *koordina* file can be made in SSIIM 1 or in a spreadsheet, and this can be transformed to an *unstruc* file using the method described in Appendix I.

The unstruc file is usually very large. If this is a problem, then it is advisable to use as few cells in the vertical direction as possible when making the file. The number of cells in the vertical direction can then be increased later by adjusting the *G 1* and *G 3* data sets the *control* file.

The *unstruc* file has to contain the water discharges at the correct locations for inflow and outflow. This is specified in the *Discharge Editor*.

It is recommended to use the *F 102 1* data set in the *control* file to make the grid cells along the boundary change in shape to improve the smoothness of the banks. However, the *F 102 1* option should never be used before the *unstruc* file is saved. Insert the *F 102 1* in the *control* file after the *unstruc* file has been made.

When the *unstruc* file is made, its water level is often higher than what the user wants in the start of the computation. This is especially the case when modelling wetting/drying situations. To specify that a lower water level is used at the start of the computation, two steps have to be taken:

1. Make a *koordina* file containing the desired initial water level
2. Add the *F 112 1* data set to the *control* file

This *koordina* file has to have the same grid coordinates for the *x*, *y* and bed levels as in the initial *unstruc* file, but it also has to contain the water levels. A recommended procedure is to use the file *koordina.t*, which is written automatically when the initial *unstruc* file is written from SSIIM 2. The *koordina.t* file has the correct values for *x*, *y* and the *bed levels*. However, the water level is the same as in the *unstruc* file. The *koordina.t* file can be imported into a spreadsheet and the values for the water level can be changed to the desired initial values. Then it can be written to the working directory and named *koordina*, without an extension.

Note that the *F 112 1* option in the control file only works with the original *unstruc* file and the modified *koordina* file. If later during the computation a new unstruc file is written from the menu, then this will not be compatible with the modified *koordina* file. Writing a new *unstruc* file during the computation will overwrite the original *unstruc* file. In other words, keep a safe copy of the original *unstruc* file and the modified *koordina* file. To reduce the occurrence of this common mistake, the *unstruc* file will get an extension .dry if it is written when some part of the geometry has dried up. Also, the user will not be allowed to enter the *Grid Editor* or the *Discharge Editor* when the *F 112 1* option is used in the *control* file.

The lateral movement of the grid is due to fluctuations in the bed and water levels. This means that one or both the *F 36* and *F 37* data sets have to be used in the *control* file. Also, the *timei* file has to be used, where time-variations in water level, water discharge and sediment inflow can be given.

As the computation proceeds over time, intermittent results may often be required. This can be done by using the *P 10* option in the *control* file. A number of *bedres* and *result* files are produced, which can be read by SSIIM 2 at a later time after the program has finished. This is done by removing the extensions of the files at the selected iteration and reading the results from the menu of SSIIM 2. Using the *F 389* data set in the *control* file, similar writing of *alldata* files is invoked.

3.8 Nested grids

Nested grids are used for resolving finer scale problems in some part of the geometry. The nested grids can only be used in SSIIM 2. They are generated using the *Grid Editor*.

Several nested grids can be used. The numbering of the grids are important and must be kept in mind when giving information later in the *control* file. The first grid generated is numbered 1, second 2 etc., whether they are nested or not.

When making a system with nested grids, some decisions have to be made regarding the order of solving equations for the different grid parts, and which equations to solve. The specification of which grid is to have its water flow computed is determined on the *G 25* data set. This data set reads a number of integers. The number of integers must be the same as the number of grids. The integer gives the order of the computation. For example:

G 25 3 1 1 2

The first integer on the *G 25* data set says there are three working blocks. The two first blocks are computed first, as they have number 1. The third block is computed afterwards. The third block may be a nested block. The computation will then first be done on the main grid, and then on the nested grid afterwards. To compute all blocks at the same time, including the nested block, the following data set can be given:

G 25 3 1 1 1

Note that the default method is to compute all blocks at the same time, so then it is not necessary to specify the *G 25* data set.

If one block is not to be computed at all, a zero can be given. For example:

G 25 3 0 0 1

Then only the last grid is computed. This can be used when the bed changes only happen in the last block, and the water flow does not change in block 1 and 2. Then the steady water flow field is computed first, and the result file written. The result file is read before the unsteady computation is started.

The water flow is computed using the procedure above for each time step. Afterwards, the sediment transport may be computed. The specification of which block to compute the sediment is given on the *F 188* data set. The *F 188* data set only has one integer. If it is 0 (default), sediment transport will be computed in all blocks. If the integer is a positive number, only the block with this number is computed. If the integer is negative, all nested blocks are computed.

Importing nested grids

The typical application of nested grids can be local scour or investigating something at a smaller scale than what is given in the coarse grid. The coarse grid is then used to find the boundary conditions as for example the upstream velocity profile for the smaller domain. Then it is possible to make the grids in two parts. First, a fine grid is made of the smaller domain, for example around a bridge pier this grid is stored in a *koosurf* file, giving the vertical level of both the bed and the water. This file can be made in SSIIM 1 or SSIIM 2. This file is then imported into the SSIIM 2 grid editor. The *koosurf* file must be renamed *koosurf.nes*, before it is read into SSIIM 2. Also, an additional line must be given at the beginning of the file. This line must start with the integer 999999 or 999998. Then six integers and five floating point numbers must follow.

The first four integers describes an outblocked region in the nested grid. This is used to block out a region of the nested grid, for example if one is to model flow around a cylinder. The four integers will have the same values as the 2nd to 5th integer on the *G 13* data set. If no outblocking is to be used, the integers should be set to zero. It is still recommended to use the *G 13* data set in the *control* file to block out the cell in the coarse grid. Then the *j* values need to be increased. The new numbers are most easily found in the *GridEditor*, showing the grid indexes.

The following two integers gives the indexes for the center of the nested grid. This could typically be the *i* and *j* values of the center of a cylinder, if the nested grid contains a cylinder.

The following two floating point numbers gives the coordinates in *x* and *y* direction of the center of the nested grid. The values are given in the coordinate system of the coarse grid. The nested grid will thereby be moved to this location in the nested grid.

The three last floating point numbers on the line are: *scaling parameter*, *rotation* and *water level*. The *scaling parameter* will scale the nested grid. If a scaling is not wanted, a value of 1.0 should be given. The *rotation parameter* is a value in degrees, where the nested grid will be rotated around its center in the clockwise direction. The *water level* is a parameter which is used to specify a water level if it is different than the values in the *koosurf* file. The value is only used if the first number on the line is 999999. If the number is 999998, the original water level of the *koosurf* file will be used. However, a value must still be given, so that the total line will contain seven integers and five floating point numbers.

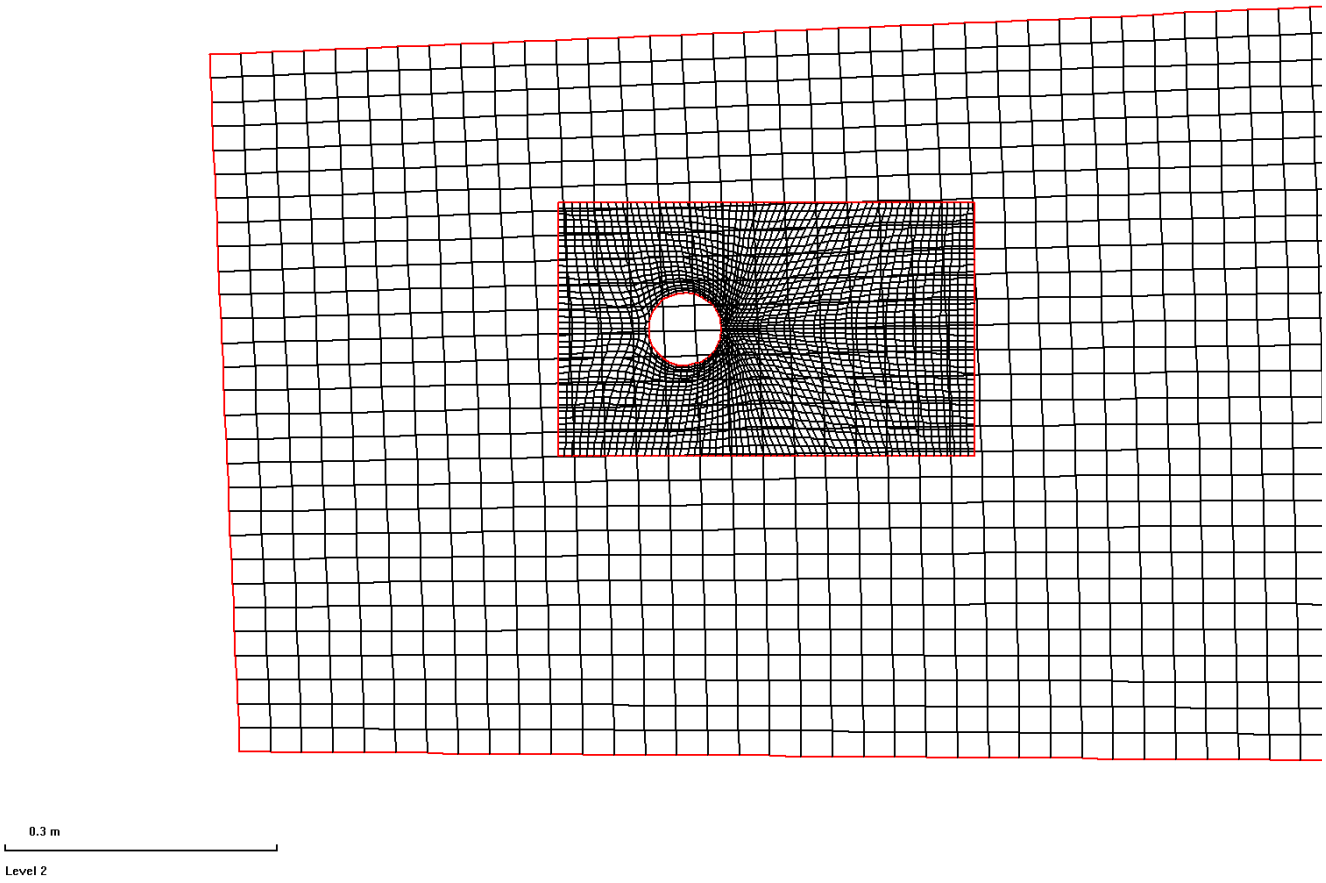
Then the coarse grid is made of the larger domain, for example a river. Afterwards, the fine grid is imported into the coarse grid domain using the *GridEditor*. The menu option *Block → Add nested block from koosurf* is used.

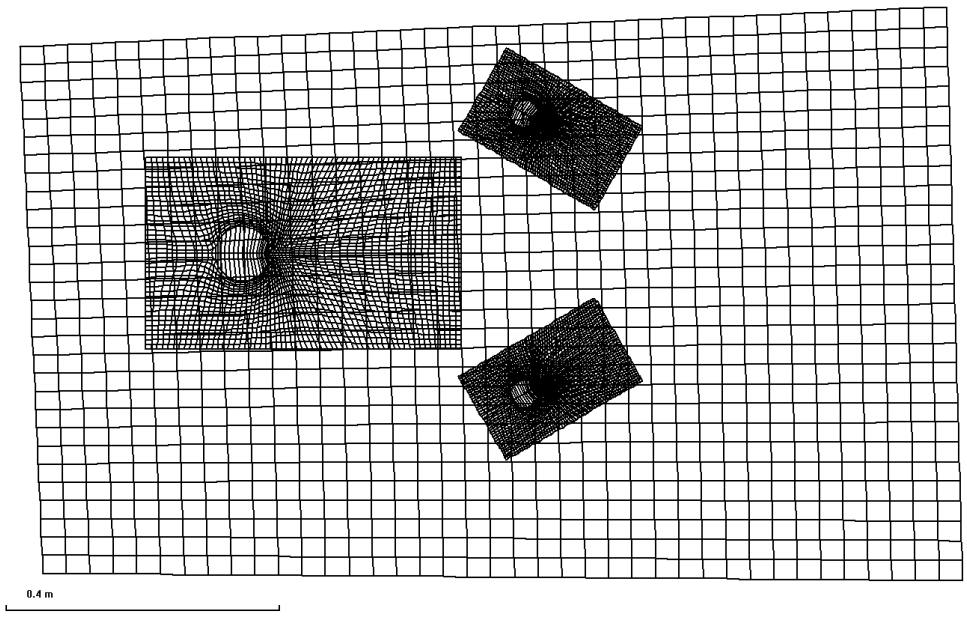
Note that multiple *koosurf.nes* files can be imported. Let us say that two *koosurf* files are made of two bridge piers. The two files are given the names *koosurf.1* and *koosurf.2*. Then the coarse grid is made in the *GridEditor*. Then the *koosurf.1* file is copied to the file *koosurf.nes*. Then the *koosurf.nes* file is imported into the *GridEditor*. Then the *koosurf.2* file is copied to the *koosurf.nes* file. Then the new *koosurf.nes* file is imported into the *GridEditor*. This can be repeated several times with multiple nested grids.

It is also possible to just change the first line in the *koosurf.nes* file between importing new nested grids. For example the location of the center of the nested grid.

The figures below shows how the grids may look with a combination of coarse and nested grids.

The actual *koosurf.nes* file used in the figures below to model a circular cylinder with a nested grid can be found on the web page: http://folk.ntnu.no/nilsol/ssiim/koosurf.nes.


0.3 m
Level 2


0.4 m

3.9 Displaying measured bed changes in SSIIM 2

It is possible to use the bed interpolation algorithms in SSIIM 2 for visualizing measured bed elevation changes. The measured bed elevations at two different times are used. The values can be exported to Tecplot or Paraview for nice 3D colour graphics. The volume of the changes can also be computed.

The following steps must be taken:

1. First a grid has to be made of the geometry. The grid would typically be made from a *geodata* file, taken from the assumed lowest bed levels. For example after the flushing, or before sediment deposition. The grid is then written to the *unstruc* file. When this file is written, a file called *koomin.bed* is also written. Rename this file to *koomin.bed1*, so it is not overwritten later. Note that a *koomin* file must not exist in the directory when the *unstruc* file is made.

2. Add an *F 249 1* data set to the *control* file. This will allow both positive and negative values of the bed elevation changes. Make sure you are using a SSIIM 2 executable made after 14. February 2010.

3. Use the same grid as in point 1, but now change the *geodata* file to the one from the other bed level. Use this file to make a new bed level with the same grid as in point 1. Make sure there is still no *koomin* file in the directory. Write the *unstruc* file.

4. Rename the *koomin.bed1* from point 1 to *koomin* without an extension. Then start the program with the *unstruc* file from point 3 and the *koomin* file from point 1.

5. The variable *sediment thickness* will now be the difference between the two bed levels from the two *geodata* files. This can be displayed in the SSIIM 2 graphics, or written to the ParaView or Tecplot files. If the variable does not show up when the Tecplot/ParaView file is written directly from the menu, it is necessary to add the parameter *t'*on the *G 24* data set and use an *F 48* option in the *control* file to produce the Tecplot/ParaView file when writing the *result* file.

6. The initial water volume of the reservoir is written to the *boogie* file at the beginning of each transient sediment computation. Using the two *unstruc* files from point 1 and 3 will give two volumes for the reservoir. As long as the water level is the same, the difference in volumes will give the volume of the deposited/eroded sediments in the reservoir.

Chapter 4. User interface

4.1 The main user interface

The main user interface appears once the program is started and the input files are read or generated.

The Windows version consist of only one window with one menu. At start-up, the window show text with information about convergence and the run, similar to the dialog box in the OS/2 version. The content of the window can be changed by choosing different sub-options in the *View* option of the menu. Each *View* option will correspond to a window in the OS/2 version. Changing the *View*, will also change the main menu. The different *Views* are:

- Map graphics with contour plots or vectors
- Longitudinal/cross-sectional profiles
- *Grid Editor*
- Discharge Editor (SSIIM 2)

The options are described in more detail in Chapter 4.2-4.4. The main menu also has options for reading and writing input/result files, starting computations or printing. A sub-option of *View* decides if colors should be used or only black lines.

In general, a SSIM run should be started by reading input files, or generating the grid using the *Grid Editor*. After generation of the grid, the inflow and outflow should be specified using the *Discharge Editor*. Then the data should be saved in the *Unstruc/koordina* files, before the computations are started and the results are viewed.

4.2 Interactive input of parameters

Some of the most commonly used parameters can be set in dialog boxes in the OS/2 versions. These dialog boxes are activated by the Input Edit choice in the main menu bar. The choices are:

GridEditor:	This option is described in Chapter 4.3.
DischargeEditor:	This option is described in Chapter 4.4. (Only SSIIM 2)
Waterflow parameters:	This gives various parameters for calculation of water flow, which can be used when there are convergence problems and when parameter tests are done. Some of the parameters can be changed while the program is calculating the water flow field.

Note that only the most commonly used parameters can be given in the dialog boxes. The other parameters have to be given in the *control* file.

Usually, it is not recommended to use the dialog boxes. When running many cases with different input parameters, each run is usually done in a separate directory. This directory will then contain both input files and the results. The system is more convenient for archival purposes, when later looking at which parameters in the input files were used to create certain results.

4.3 The *GridEditor*

The *GridEditor* is invoked from the *View* option in the main menu. The grid is seen from above.

SSIIM 1:

In SSIIM 1, a structured grid is used. When starting the *GridEditor* without reading a previously generated grid, a rectangular grid is shown as default. The left side of this rectangular grid is the default water inflow. The right side is the default water outflow. In the Windows version of SSIIM 1, the default inflow side is coloured red. And the default outflow side is coloured green.

When generating a grid for a natural geometry using *geodata* points, the inflow of water is often not on the left side, and the outflow not often on the right side. The grid therefore has to be rotated initially. This is most easily done by moving the corners first, and then using the menu options *Sides* and *Transfinite I*. The menu options are described more in the following.

General:

The menu bar gives various options for generating the grid. In the following, the grid generation procedure is described first, and then the different menu options.

4.3.1 The grid editor menu

The main menu of the grid editor is made up of several options with corresponding sub-menus. The structure of the menu depend on which version of SSIIM is used.

View

In the Windows versions of SSIIM, the *View* option has a sub-option *Geodata points*, displaying the points in the *geodata* file in the grid window. The points are shown with a circle, and the different colours indicate different vertical levels. Note that the points are read from the file, and this may take some time if the file is large. If the file is very large, not all points may be shown in the window. This can be changed from the menu.

Move/Scale

The option Move is used to move the plot upwards, downwards or sideways. The arrow keys can be used instead of the menu. The option Scale is used to enlarge, shrink or distort the plot. The keys <Page

Up> and <Page Down> can be used for scaling. By holding down the <ALT> button while scaling/moving, then the changes are smaller.

Define

This option is used for defining different parameters. The parameters are often connected to grid intersection points. The point that was last activated by the mouse is used as default.

The first option is *Give coordinates*. This gives a dialog box where the user can give numerical values for *x,y* and *z* for a grid intersection.

The second option is *Set NoMovePoint*. This invokes a mode where the user can define certain points which will not be moved by the interpolation, called *NoMovePoints*. In NoMovePoint mode it is not possible to move the grid points with the mouse. When the user clicks on a grid intersection, a blue star emerges on the intersection as a sign that this is chosen. Up to 19 999 NoMovePoints can be chosen. To verify that this mode is present, the letters "Point mode, 0" is shown on the lower part of the EditWindow when the Set NoMovePoint is chosen. The integer shows how many points you have chosen. To return to the normal mode, choose Define and Set NoMovePoint again. It is verified that the normal mode is set because the text "Point mode" disappears. In the normal mode the user can move all points including the NoMovePoints.

The third option is *Delete NoMovePoint*. This deletes the last point set under the NoMovePoint mode.

The following four options are setting of attraction to certain points or lines in the grid. This is used by the elliptic grid generator. A dialog box emerges when the choice is made, and the user must give two integers which describes the location of the attraction point/line. Then two attraction parameters are given. The *Prop. att.* value is proportional to the attraction. If negative, the grid lines are moved away instead of attracted. The *Sq. att.* value gives an attraction proportional to the grid line difference raised to a power of *Sq. att*. This value is used to determine how far out in the grid the attraction works. Note that a smaller value will give larger attractions.

Point attraction gives attraction to points, and *Line attraction* gives attraction to lines.
Up to 200 attraction points can be defined. The attraction points can be seen on the grid by coloured rectangles at the grid intersections.

The last option in the *Define* menu is *Delete last attraction*. This deletes the last defined attraction.

Generate

The first choice in the pull-down menu is *Boundary*. This choice interpolates linearly along the four border lines of the grid. Note that the *z* values of the bed are also interpolated. This will create a rectangle unless a *NoMovePoint* has been defined on the border. Then the interpolation will be between the corners and the *NoMovePoints*.

The second choice is *Elliptic*. This starts the elliptic grid generator. Note that this will not change the

bed levels.

The third choice is TransfiniteI. This is transfinite interpolation in the streamwise direction. The z values will be interpolated. IMPORTANT: In this mode the NoMovePoints will also be moved.

The fourth choice is *TransfiniteJ*. This is the same as *TransfiniteI*, except it is in the lateral direction.

The second last choice, Bed levels/Bed interpolations, generates *z* values for the bed surface of the grid. The *z* values are interpolated from a set of geometrical data read from the *geodata* file. If there is no *geodata* file present, an error message is given. The interpolation routine goes through all the grid points (*i,j*), and finds the closest points in the *geodata* file in all four quadrants where the grid intersection (*i,j*) is the centre of the coordinate system. Then a linear interpolation from these four points is made. If one of the points in the *geodata* file is closer than 5 cm from the grid point, this *z* value is chosen and no interpolation is done. The outcome of the interpolation is logged to the file boogie.bed. If the interpolation routine is unsuccessful in finding the point, the *z* value is set to zero.

The last choise, *3D Grid/Implementation*, is used after having changed the *z* values on any of the coordinates. The *GridEditor* only moves the grid in the layer bordering the bed. So if any of the grid points have been moved in the vertical direction, the water level and the grid points above the bed needs to be recalculated. The new grid is computed by using the *3D Grid* option.

4.3.2 Grid generation for SSIIM 2

SSIIM 2 uses two grids: a two-dimensional depth-averaged structured grid and another three-dimensional unstructured grid. The two grids cover the same area. The 2D grid is fixed in space over time and contain both the wetted and dry cells. The indexing of the 2D grid is similar to SSIIM 1. The 3D grid may change over time as the water and bed elevations change. The total number of cells in the 3D grid will therefore also change, and also the indexing of the cells.

For a real-world case where a complex water body is simulated, it is necessary to start with a *geodata* file, giving the coordinates of for example contour lines of the bed levels of the lake.
The grid generation procedure then starts with reading this file from the *Grid Editor*. The individual points will then be shown in the main window, with different colours according to the vertical elevation.

It may not be necessary to use a *geodata* file for demonstration and teaching purposes, or if the geometry is fairly simple, for example a channel.

The next step is to start making a number of blocks in the *Grid Editor*. Each block is made up of a structured grid, which is 2D depth-averaged. The blocks are glued together to form an unstructured grid, covering the whole water body. The blocks can have different number of cells, both related to other blocks and the two horizontal directions.

With the most recent wetting/drying algorithm, it may be most convenient to make a single 2D block of the geometry. The wetting/drying algorithm can then be used to make the complex boundary.

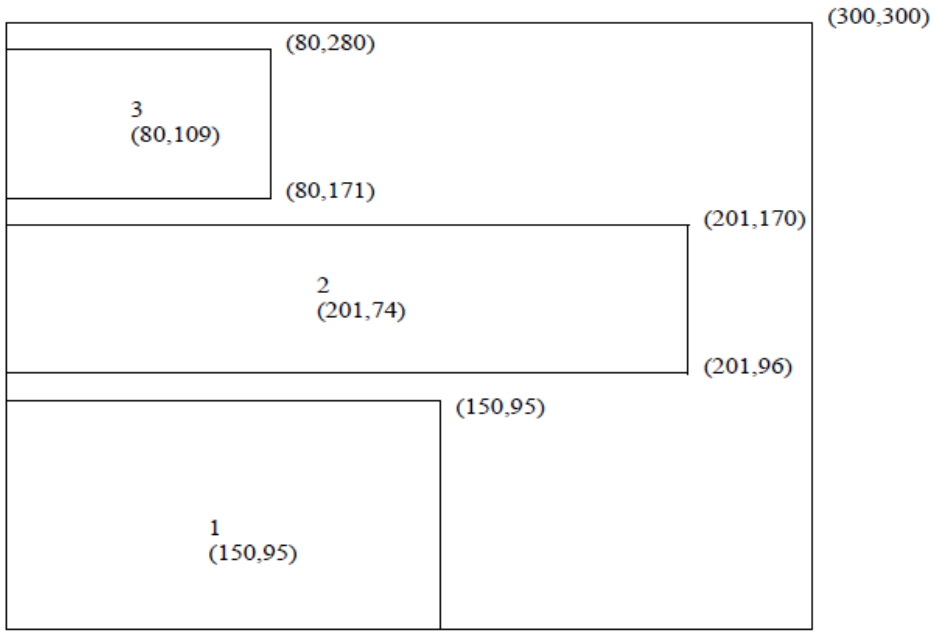
When the plan view of the grid looks ok., the 3D grid can be generated. This grid is based on the 3D grid, but has a varying number of grid cells in the vertical direction. The 3D grid is generated in the *Grid Editor*, from the menu options *Generate -> 3D grid*. Afterwards, it is advisable to save the grid from the main SSIIM menu, by writing to the *unstruc* file.

Note that the unstruc file will not contain the 2D grid, only the 3D grid and a connection between the 2D grid and the 3D grid. The *unstruc* file should therefore only be written when all the 3D cells are fully wetted, and no section of the 2D grid is dry.

It is also recommended to read Chapter 6.11 to get more information about this topic.

Multiple blocks in SSIIM 2

SSIIM 2 has the option of using multiple blocks. The blocks can be glued together. Each block is stored in one large block. This is seen in the figure to the right. The large block has by default 300 x 300 cells dimension. This can be changed with specifying different parameters on the *G 1* data set.



The figure above shows the *i*-direction to the left and *j*-direction upwards. Let us say that the first block has 150 cells in the *i*-direction and 95 in the *j*-direction. Then the second block has 74 cells in the *j*-direction. This means that the second block will be placed at *j*-values between 96 and 170 in the initial main block. It also means that there is only 300-170 = 130 more *j*-spaces in the main block. If many blocks are created, they may fill up the main block in the *j*-direction. This needs to be kept in mind, and the *G 1* data set must be adjusted accordingly.

Details of grid generation

For real-world cases, it is important to make a hand-drawn sketch of the geometry and the grid blocks before making the grid on the PC, to determine the approximate size and number of blocks. Note the

limit of number of blocks is currently 19. It is possible to add blocks to an already existing grid, so usually it is advisable to start with a simpler grid with a couple of blocks covering the main part of the water body, and add more detail afterwards. Also note that it is not possible to remove already added blocks, so it may be advisable to save files with the simplified grid.

The blocks are added by choosing the *Add block* in the *Block* menu. After making the choice, the user clicks with the mouse on the four corners of the block. The four points must be added in the clockwise direction, starting with the south-west corner, then the north-west corner, then the north-east corner and finally the south-east corner. Note that the directions north-south-east-west does not have to follow the true directions according to the map, but it has to be consistent relative to the rest of the grid. After the four clicks are made, a rectangle is seen on the screen. The user then have to choose the number of grid cells in the block. This is done by choosing the *Size block* in the *Block* menu, and giving the numbers in the dialog box. The grid lines in the block then emerge. The user can now move the grid lines of the block to better fit the boundary or other characteristics of the desired grid.

A new block is added by the repeating the same procedure, starting with *Add block*. Up to 19 blocks can be used.

The next step is to glue blocks together. The connection is actually made in the three-dimensional generation procedure. The algorithm checks if two grid points are very close to each other. If two grid lines at borders of two grids are very close, then the connection is made. Note that the ends of the grid lines also have to be located at the same place, so that only one cell from one block connects to one cell at another block. It is not possible to have two cells from one block connecting to one cell in another block. Then the connection is not made, and a wall is used instead.

Before the 2nd block is made, one should think about the orientation of the blocks. The new block will similarly to the first block have a south/west/east/north side. When the blocks are glued together, the north side of one block should be glued to a south side of the other block, for example. Or the east side of one block should be glued to the west side of another block. Thereby a consistency of the direction of the total grid is maintained. All the blocks should have the same north/east/west/south direction.

To make the connection it is therefore necessary to locate grid corners from two blocks at the same place. This is done by choosing *Connect points mode* in the *Block* menu. In this mode, it is possible to click on one grid corner and drag it to another grid corner in another block. When this is done, the point is locked, and will not move later, similar to a *NoMovePoint*. This is seen in Figure 4.3.2.1. Fig. A shows two blocks that are to be connected. Fig. B shows the connection of two border grid points

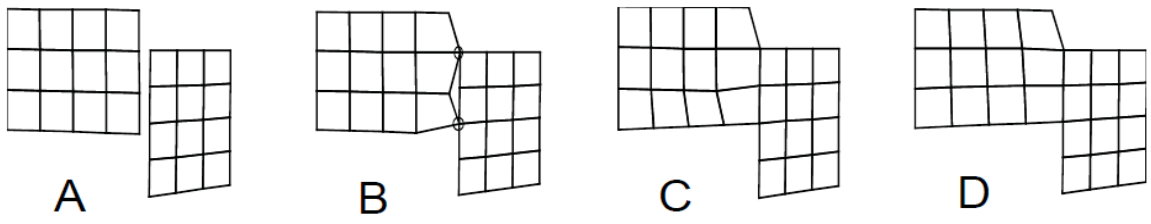
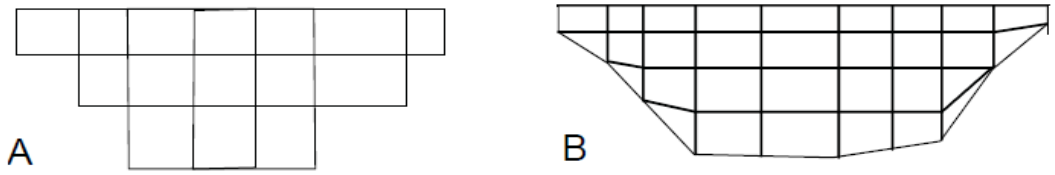


Fig. 3.3.2.1 Procedure to glue blocks together.

It is not necessary to connect all the points along a connection, only the end points. For each block, one can use the *Generate - Boundary* option to generate straight lines between corner points, *NoMovePoints* and *Connection* points. Then the intermediate points on the connection line will be located at the same place. This is done in Fig. 4.3.2.1 C above. Note that it is only possible to edit one block at a time. The user choose which block to edit by the menu option *Block - Choose no*.

After the blocks are made and glued together, it is usually necessary to modify each block boundary according to the points in the *geodata* file, and also possibly to generate the initial points in the block with the elliptic or transfinite grid generator. This is shown in Fig D above. The user can click with the mouse on a grid intersection and drag this to a new location. The mouse button must be pushed down while the movement is made.

When the user is satisfied with the two-dimensional grid, the grid has to be made in the third direction. This is done in the Three-dimensional grid option in the menu. It is possible to have varying numbers of grid cells in the vertical direction. There are basically two ways to do this. Either to have a stepped grid with horizontal grid lines, or using non-horizontal grid lines including the possibility of having triangular cells. The two options are given in the figure below:



Note that A (*F 64 0*) is no longer the default option. When using this option, then the levels of the grid lines (in meters) must be given on the *G 3* data set. Option B can be specified using the *F 64* data set (currently default). When using the *F 64 11* and *F 64 13* options, the values on the *G 3* data set are not used.

The horizontal grid lines are often preferred when calculating lakes where density stratification is very important. Then the absence of non-orthogonal terms for a non-orthogonal grid may cause instabilities. Also, for a lake with stratification, most of the velocities occur close to the surface, and if the grid is not exact at the bed, this may not affect the results. The non-horizontal grid lines are used where a very accurate description of the bed is necessary, and where density gradients are relatively small.

In the *Three-dimensional grid -> parameters* dialog box, the user chose the grid type and the vertical distribution of grid lines.

If the user wants to create a nested grid, the menu option *Add block* should be chosen. The user chooses the corners of the nested grid inside the already generated coarse grid. But instead of choosing *Block size*, the option *Nested block* should be chosen. Then a dialog box is given, where the user choose parameters for the nested block. The nested block is automatically connected to the rest of the grid in the three-dimensional generation of the grid.

Important notes:

1. After having edited the grid, it is advisable to write the content to the *unstruc* file. This is done in the *File* option of the main menu. Also note that the 3D grid first have to be made, using *Generate* and *3D grid* in the menu.

2. Using unfavourable attraction coefficients can cause the elliptic generator to crash, which means that SSIIM also crashes, and the grid data are lost. It is therefore advisable to write the grid to files before starting the elliptic generation with attraction coefficients. If the program crashes, the files can be read and other attraction coefficients can be tried.

Using the latest wetting/drying algorithms of SSIIM 2, it is often best to use only one block. Then the water level is chosen so high that it is above the bed at all places. Additional *geodata* points may be generated in areas where there are too few points. An *unstruc* file is generated for the block, where no drying has taken place. This unstruc file is then used in all following computations. Inflow/outflow is specified in this file. Often, the water level at the start of the computation is below the highest water level. Then a koordina file is made with the initial water level, often using a spreadsheet to modify the *koordina.t* file. The *F 112 1* data set is used when reading the *unstruc* file. This causes the original *unstruc* file to be read first, then the *koordina* file with the lower water level is read, and then the grid is regenerated to the lowered water level. IMPORTANT: The unstruc file must not be written after this procedure, when the water level has been lowered. Only the original *unstruc* file must be used in the following work. Otherwise, no geometrical information will be stored for the dry areas, causing problems later.

4.3.3 Digitizing maps (SSIIM 2 for Windows only)

It is possible to use SSIIM 2 for Windows to digitize maps in order to generate the *geodata* file. A digitizing table have to be used, and the drivers have to be installed properly. The digitizing table mouse will then show a cursor moving along the screen. SSIIM uses the location of this mouse to generate coordinates.

The *Grid Editor* in SSIIM is used. First, SSIIM is started, and the window maximized. Then the tablet mouse is moved so that the cursor is in the lower left corner of the inside of the SSIIM window. A pencil is used to mark this point on the tablet. This point is called *A*. Then the tablet mouse is moved so that the screen cursor is at the upper left corner of the inside of the SSIIM window. This is point *B*. The distance between the points on the digitizing table is measured using a ruler. This is called *D*. The inverse of the scale of the map is multiplied with *D* (in meters) to obtain the number *S*. For example, *D* is 37 cm, and the scale is 1:3000, then *S* is 1110 meters.

In the working directory, an initial *geodata* file have to be made, using an editor. The file should have three lines:

S 0.0 0.0 1110.0 1110.0
E 0.0 0.0 0.0
Z 0 0 0

The two last floating point numbers on the first line is *S*. Replace 1110.0 with the computed *S* value from your case.

Then tape the map to the digitizing table and start SSIIM. Choose the *GridEditor,* choose *View geodata points* and *Define->Add geodata points*. Give the level of a contour line in the dialog box, and click on the line on the map on the digitizing table with the tablet mouse. Chose *Define->Add geodata points* again when a new contour line is digitized. Do not digitize more than 500 points at a time, then SSIIM will crash. Before 500 is reached, the *geodata* file should be saved and SSIIM ended. Then start it up again, read the *geodata* file and add new 499 points. This can be repeated as many times as necessary.

Note the map have to stay at the same place on the digitizing table. If it is removed, the coordinate system will move, and the digitizing procedure have to be repeated.

After the digitizing is done, the first line with the *S* data set should be removed from the *geodata* file, and the scaling/moving of the graphics will work again.

Also note it is possible to remove *geodata* points graphically in the SSIIM 2 *GridEditor*.

4.3.4 Bed interpolation algorithms

The algorithms provide a method to interpolate the bed levels of the grid, given a large number of measured points, randomly distributed on the bed. The measured points are given in the *geodata* file.

There are currently three algorithms implemented in SSIIM 1 for Windows:

- The default algorithm
- The minimum algorithm
- The cross-section algorithm

Only the first one is currently implemented in SSIIM 2 and the OS/2 versions.

In the following, the index p is given for the point where the algorithm computes the bed level. The algorithm then computes z_p, given x_p, y_p and a number of *geodata* points: (x_i,y_i,z_i).

The default algorithm

The default algorithm divides all the *geodata* points in four groups, according to their position in the *x*-*y* plane. The first group has both larger *x* and *y* values than point *p*. The second group has larger *x* values and smaller y values. The third group has smaller x and y values than p. And the fourth group has larger *x* values and smaller y values. From each group, the point closest to p is then chosen. This gives normally four points, all surrounding point p. A linear interpolation of the zp value from these four points is then done, based on the inverse of the distance from the points to p. The following line is written to the *boogie.bed* file:

First: 10 20 345 456 345 321

The two first integers are the i and j indexes for point *p*. The four following indexes denote the four surrounding points. The numbering follow the order of the points in the *geodata* file. The first point in the geodata file is 1, the second 2 etc.

Some special algorithms are used if there are no *geodata* points in one or more of the groups. If there are no points in two or more groups, then the algorithm may fail. Then a zero z_p value will be given to point *p*. Also, the following warning message will be written to the *boogie.bed* file:

Warning, null value first loop for i,j=10 20

For this example, *p* is located at (10,20).

It is recommended to check this after a bed interpolation, or look at the contour map of the bed levels. This should be checked for areas where the bed level is zero. If this occur, the z_p level should be given in the *koordina* file, using an editor.

Also note that if a *geodata* point is located within a distance of 0.05 meters from p, then the z value of this point is used instead of the interpolation. Then the following line is written to the *boogie.bed* file:

Using exact value for 10 20 4.567

In this case, the value for point (10,20) is 4.567 meters.

Note, the value 0.05 meters can be changed by the user, by giving it on the *F 47* data set.

The minimum algorithm

This algorithm was developed during the work with the Sokna river in 1994. The Sokna river had very large stones, and a porosity approach was used to include their effect. The *geodata* file contained a large number of points for each grid cell, and the default bed interpolation algorithm gave the average bed level of the surrounding measured points. For this case, we thought this was a too high value. A lower value would better enable modeling the flow close to the bed, between the stones.

A similar procedure to the default algorithm is initially used, where the *geodata* points are divided into the same four groups. Then the average cell size close to p is computed, and all points further away from p than this are discarded. In each of the four groups then the following two parameters are computed:

- the average bed level
- the minimum bed level

This gives altogether eight numbers in the four groups, if there are sufficient *geodata* points available. The eight points are then averaged, by adding them and dividing by eight. This gives the bed level in point *p*.

This algorithm gives a lower bed level, and often a smoother bed.

If there are no points in any of the groups, the algorithm will fail. The bed level in point p is set to zero, and the following error message is written to the boogie.bed file:

Could not use internal interpolation for i,j=10 20

If there are no points in one of the groups, the following warning message will be written to the *boogie.bed* file:

Warning, using skewed value for i,j= 10 20

This algorithm will not use the exact value of one of the *geodata* points, if this point is very close to *p*.

The cross-section algorithm

This algorithm was developed as an attempt to give a better bed interpolation if the geodata points are taken from measured cross-sections. This is often the case, as cross-sections are traditionally measured for one-dimensional numerical models.

It is now assumed that the modeled geometry resembles a river, and that the grid lines follow the streamlines reasonably well. And that the cross-sections are reasonably normal to the flow direction and the grid lines in the longitudinal/streamwise direction.

At point p, two vectors are first computed: along the grid line in the downstream direction, and in the upstream direction. Then the vector from p to each of the geodata points are computed. The dot product between this vector and the vector in the downstream grid direction is computed, to see if the two vectors are parallel. Also, the distance to the geodata points are computed, to select the geodata points in the closest cross-sections. (upstream and downstream of *p*). The two points forming the smallest angle on the left and right side of the grid line vector are selected. A linear interpolation between the points are done, based on the angles. This gives one bed level for the downstream direction. Then the same is done for the upstream direction. The two values are then linearly interpolated, based on the distance between the selected *geodata* points and point *p*.

The algorithm basically interpolates between four *geodat*a points. The number of these points are written to the *boogie.bed* file:

Internal: 10 20 345 346 453 454

As for the default algorithm, the exact value of the *geodata* point will be selected if the point is within a distance 0.05 meters from p. The same message will then be written to the *boogie.bed* file.

Using exact value for 10 20 4.567

If for example there are no cross-sections at one side of the grid point, the outcome of the algorithm is not determined. If the algorithm does not find any points, zero indexes will be written to the *boogie.bed* file, for example:

Internal: 10 20 0 0 453 454

Then it is advisable to check the bed levels for these points.

4.3.5 Displaying measured bed changes in SSIIM 2 for Windows

Measured bed changes can be displayed in SSIIM 2 by using the following method:

1. First a grid has to be made of the geometry. The grid would typically be made from a *geodata* file, taken from the assumed lowest bed levels. For example after the flushing, or before sediment deposition. The grid is then written to the *unstruc* file. When this file is written, a file called *koomin.bed* is also written. Rename this file, so it is not overwritten later.

2. Add an *F 249 1* data set to the *control* file. This will allow both positive and negative values of the bed elevation changes. Make sure you are using a SSIIM 2 executable made after 14. February 2010.

3. Use the same grid as in point 1, but now change the *geodata* file to the one from the other bed level. Use this file to make a new bed level with the same grid as in point 1. Write the unstruc file

4. Start the program with the *unstruc* file from point 3 and the *koomin* file from point 1. The koomin file must now be called *koomin* and it must not have any extension.

5. The variable "sediment thickness" will now be the difference between the two bed levels in the two geodata files. This can be displayed in the SSIIM graphics, or written to the ParaView or TecPlot files. If the variable does not show up when the Tecplot/ParaView file is written directly from the menu, it is necessary to add the parameter '*t*' on the *G 24* data set and use an *F 48* option in the *control* file to produce the Tecplot/ParaView files.

6. The initial water volume of the reservoir is written to the *boogie* file at the beginning of each transient sediment computation. Using the two *unstruc* files from point 1 and 3 will give two volumes for the reservoir. As long as the water level is the same, the difference in volumes will give the volume of the deposited/eroded sediments in the reservoir.

4.4 The *Discharge Editor* (SSIIM 2)

Because the SSIIM 2 grid is unstructured, it is not possible to give water discharges and flow of other constituents in the *control* file. The number of the grid lines are not easily obtained. Instead, the discharges are given in the *Discharge Editor*. The values and locations are stored in the *unstruc* file.

The *Discharge Editor* is invoked from the *View* option in the main menu of the Windows versions of SSIIM 2. It is somewhat similar to the *GridEditor*, in that the grid is shown in the main menu. The user

can choose between two types of discharges: side discharges, for example inflow from an upstream river, or surface discharges, for example a pollutant spill in the center of a lake.

Side discharges

The side discharges are organized in ten groups. Each group has a water discharge, and some characteristics. Among the characteristics is if it is an inflow or an outflow. The user first chooses which group to give data for. Then the data is given in the dialog box emerging from the *Give values* option in the menu. Afterwards, the user chooses *Add surfaces* to define which surfaces belong to the discharge group. The surfaces are then added by clicking on the grid with the mouse. If the wrong surface is added, choose *Remove surface* from the menu.

When adding a surface to a group, the user clicks on a line which may correspond to several surfaces, placed vertically above one another. In the dialog box the user gives two integers showing the lowest and highest surface number to add.

Note if side discharges are used, there must be at least two groups: one inflow group and one outflow group. Also, the sum of the discharges in the inflow group must be equal to the sum of the discharges for the outflow group.

One line is written to the *boogie* file for each discharge group above zero. This can be used to check if the sum of the discharges are zero, and if all or too many discharge groups are used.

Surface discharges

The surface discharges are added in a similar way as the side discharges. There is also ten surface discharge groups, but they are not corresponding to the side discharge groups. Each surface discharge group only has two parameters: an integer as an index for the water quality constituent, and the amount of pollutant to add. The index correspond to the *Q* data sets in the *control* file. The two parameters are given in an input dialog box.

4.5 Presentation graphics

There are two to three graphics modules for presentation of results. These can be invoked any time during the calculation or afterwards. More than one module can run simultaneously for the OS/2 version. The modules are choices under the Graphics option of the main menu:

- 3D OpenGL colour graphics (not for SSIIM 2 for Windows)
- Contour Map (Contour map is included in Map for the Windows versions)
- Map
- Longitudinal profile
- Cross-sectional profile
- VerifyProfile
- VerifyMap

OpenGL shows an orthographic projection of grid surfaces. If no surfaces are specified on the *G 19* data set in the *control* file, the bed of the geometry will be shown. Several *G 19* data sets can be used to specify three-dimensional surfaces of the geometry. The figure can be rotated, scaled and moved. Also, the user can choose between surfaces showing colour maps or the grid. Various options for variables can be displayed with colours. Note the more detailed description of the menu commands given in the following.

The OpenGL graphics includes particle animation. Further description of the animation graphics is given in Chapter 4.7.

Map presents the geometry seen from above. It is possible to get velocity vector plots and plots and bar plots of concentration, diffusivity, k, etc. It is also possible to plot the grid and change between different vertical levels. In the Windows versions, the contour map is also given from the same menu option.

Contour map presents the variables as contour plots, seen from above. The user can give the values of the contour lines on the *L* data set in the *control* file. If the *L* data set is not given, seven contour lines will be used. These are calculated to be within the range of the calculated variable field. If the option Variable under Scale is chosen, the user can give the numerical values of the lines (OS/2 version). It is also possible to choose the number of lines. Note that if more than 7 lines are chosen, all lines will be black. Also note that if 0 lines are chosen in the dialog box, the plotting will be similar to giving no L data set in the *control* file. The values of the different lines are given on the colour scale at the lower left corner of the window. The text gives the values of the maximum and minimum values, and there are six equal interval between maximum and minimum values (default). The values in the contour map of the Windows version is given in the Text view.

Profile presents a longitudinal/cross-section profile of the geometry. Graphs with different parameters as a function of depth along the longitudinal profile is obtained. It is also possible to view the grid or the velocity vectors. It is possible to change between different longitudinal profiles. To see where the profile is located in the OS/2 version, look at the Map Graphics and choose Profile in the Variables option on the menu. For the Windows version, look at the cell numbers in both the Profile and the Map graphics. The numerical values for the plot are given on the Text view in the Windows version.

VerifyProfile presents calculated profiles of concentration or velocity at locations specified by the user. It also presents user-given data in the same plot. See the next chapter for more information.

VerifyMap presents calculated and measured velocity vectors in the same figure. See the next chapter for more information.

Graphics menu

The modules use the standard GUI for OS/2 and Windows, and have approximately the same system of menus. Starting OpenGL graphics from SSIIM is only available for the OS/2 version.

The OpenGL graphics has an option Legend. This shows the colour legend of the plot. It can be used in presentations by using a screen-capturing tool to move one of the legends to the word processor. The

maximum and minimum values are shown in the bar above the menu.

The OpenGL graphics has an option Rotate. This gives the choice of rotating the three- dimensional view around the x,y or z axis. Instead of using the menu, it is possible to use the <F3> and <F4> keys to rotate around the x-axis, the <F5> and <F6> keys to rotate around the y-axis and the <F11> and <F12> keys to rotate around the z-axis.

The OpenGL graphics also has a menu called Surfaces. This option specifies which surfaces are shown and the properties of the surfaces. There are basically two properties: the surfaces can be shown with colour shading or the grid can be shown. There are three modes to show the properties: All surfaces colour shaded (Filled), all surfaces shown as grids (Grid) or a mixed mode where the user have to define which surfaces are shown as grids and which are shown as colour shaded (User-defined grid/filled). The same menu also defines how many surfaces are shown in a specified list. This is done by the Add and Remove last options in the menu. The list is specified on the G 19 data sets in the *control* file, or defined in the dialog box, activated by the Define option in the menu. The define dialog box is used to define new surfaces or modify existing surfaces. The user basically decides the same parameters as given on the *G 19* data set in the *control* file. Note that it is possible to store the data on the *G 19* data set by writing the *control.new* file in the menu of the main program.

The option Move is used to move the plot upwards, downwards or sideways. The arrow keys can be used instead of the menu.

The option Scale is used to enlarge, shrink or distort the plot. The keys <Page Up> and <Page Down> can be used for scaling. Some of the graphs also use <CTRL> + arrows for distorting the plot.

For the OpenGL plots, sub-menu under Scale can be used to move the colour scale to red or blue. This is also visualised in the Legend view. The <F7> and <F8> keys can be used for the same purpose.

An option in the menu bar is Graph. The pull-down menu displays different parameters that can be shown.

An option on the menu bar of the OS/2 version is System or Save. The pull-down menu of System has the option Save. This is used for storing the plot in an OS/2 metafile. The names of the metafiles file will be mapfl000.met, longf000.met, color000.met, conto000.met, vprof000.met, bedfl000.met or cross000.met, depending on which of the graphics procedures that produced the file. If there is an existing file with the same name, this will not be overwritten. Instead a new file with last characters 001 instead of 000 will be written. If this exist, further increments in the number in the name will be made, until number 999.

Printing from the Windows versions is done directly with the Print option in the main menu.

Importing SSIIM graphics into documents in Windows

The Windows versions of SSIIM can copy most of the graphics (not OpenGL) to the Clipboard. This is a kind of a graphics storage space. What is in the Clipboard can be seen with the Clipboard Viewer. The Clipboard Viewer is a program that is included in the Windows operating system. It is also called Clipbook Viewer in some Windows versions. It can most conveniently be started from a command

prompt. The command prompt is started from the main Windows menu as a window. In this window, text commands can be given. Writing clipbrd <CR> starts the Clipboard Viewer. (<CR> means Carriage Return).

The Clipboard Viewer has two windows: a local one and a global one. When the Clipboard Viewer is started, the local window is often shown. This needs to be minimized. And then the global window (the other one) is maximized. The Clipboard is then ready to view the graphics. Graphics from SSIIM is copied to the Clipboard using the SSIIM menu: *Print -> Copy to Clipboard*. The image is then seen in the Clipboard Viewer.

The graphics in the Clipboard Viewer can be saved to Clipboard files. This is very convenient when storing graphics. The image in the Clipboard Viewer can also be imported directly into a document, for example a Word file, using the menu File -> Import from Word.

For some unexplained reason, it was sometimes not possible to copy directly from SSIIM into Word. It was then necessary to follow the procedure above, using the Clipboard Viewer and save the files to disk first. However, this problem seems to have been solved with the newer versions of compilers and Windows.

It is also possible to read old Clipboard files into the Clipboard Viewer, and then import the images into the Word document. This is very practical when making reports and other publications.

4.6 Verify graphics

The purpose of the Verify Graphics is to simplify comparison of the results from SSIIM with measured values. It can conveniently be used in publications and other documentation of CFD studies.

The measured values are given in the *verify* file. Almost all measured values can be shown: velocities, turbulent kinetic energy, turbulent diffusion, pressure, sediment concentration or a water quality constituent. There are two types of verification plots:

- Velocity vectors, seen from above
- One or more vertical profiles

Velocity vectors

The velocity vector verify graphics is invoked in the Map graphics of the Windows versions. A separate window is used in the OS/2 version.

For the velocity vector verify graphics, only the first pair of values in each measurement point of the *verify* file will be used. These will be displayed together with the ordinary velocity vectors. Care must be taken when deciding about the vertical elevation of the measuring points compared with the elevation of the grid cells. The vertical distances should correspond. If not, it may be possible to change the vertical distribution of the cells, on the G 3 data set. Also, the user must choose this level when

viewing the graphics. It is advisable to use a separate verify file for each vertical level of velocity measurements.

Verify profiles

The verify profile show the water body from the side/cross-section, where a number of points in the vertical have been measured at one or more locations. The profile verification shows the measurements with crosses, and lines for the calculated results.

The verify profile is invoked in a separate window in the OS/2 version, and in a separate View of the Windows versions.

The following parameters can be used:

- Horizontal velocity (see below)
- Vertical velocity
- Pressure
- Turbulent kinetic energy
- Epsilon
- Eddy-viscosity
- Sediment concentration
- A water quality constituent

Showing horizontal velocities, the x and y components can be given in the *verify* file. The verify profile graphics can then show comparisons of:

- the magnitude of the velocities
- the component in the x-direction
- the component in the y-direction
- the component parallel to the longitudinal profile (Windows only)
- the component parallel to the cross-section (Windows only)

The profile verify graphics shows the measured profiles and the calculated values in the cell closest to the location of the measurements. The profiles may be taken in a cross-section or a longitudinal profile, or any other arbitrarily aligned line in the geometry.

Separate verify files should also be made for each variable. Note the vertical velocity is treated as a scalar variable, and must be given in a separate file.

4.7 Animation

The purpose of the animation module is flow visualisation. The module displays a 3D view of the geometry, and animates the movement of a sediment particle. The movement of the particle will depend on the flow field and the fall velocity of the particle.

The animation graphics was made using the OpenGL graphics library. The modules were incorporated in the OS/2 .exe files. This was not possible for the Windows version running Windows 95 or Windows 98. The Windows versions of SSIIM therefore does not have animation graphics. A separate program with only OpenGL graphics was made to run on Windows NT. This only works for SSIIM 1 files.

The animation is a part of the OpenGL graphics. In the OS/2 versions, the menu options will refer to the Particle option in the OpenGL menu.

The main idea is to release a number of particles simultaneously from the inflow regions of the geometry. This is done when the user chooses *Release* in the menu. The default number of particles is equivalent to the number of cells in the inflow area. There is one particle for each cell. The user can change this by choosing a different number in the *Space direction option in the menu.* Space direction 2 means that every other cell will have a particle etc.

The module will guess a certain time step, and move the particles accordingly. Sometimes this will be too slow or too fast for the visualisation. The user can adjust the speed by choosing *Double Speed* or *Half Speed* in the menu. This can be repeated.

A model to take turbulence into account is also implemented. This is fairly crude, and gives a random movement according to the turbulent kinetic energy of the flow. The random movement is isotropic. Including turbulence or not is determined by the options *No Turbulence* and *Include Turbulence* in the menu.

When the particles hit the boundary, there are two options: the particles can stick, or be reflected. This is given by the user in the *Boundary* choice in the menu.

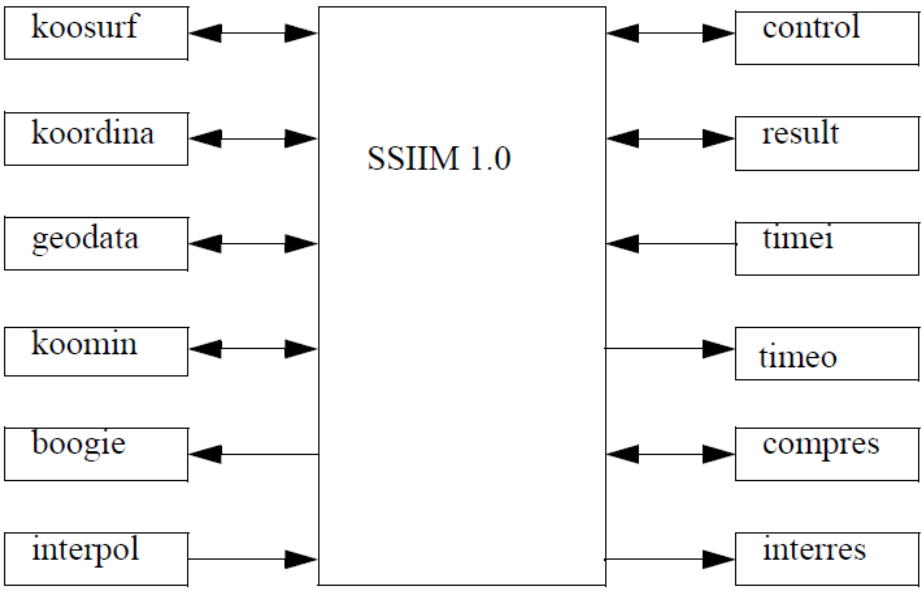
The fall velocity of the particles can also be given by the user in the *Fall velocity* option of the menu. Sedimentation can thereby be visualised.

Chapter 5. Input/result files

5.1 The file structure

The OS/2, Windows and Linux versions use the same input files and produce the same result files. The files can be interchanged between the versions. All files are ASCII files, and can be edited with a standard editor. Some of the files can also be made with a spreadsheet.

A flowchart describing the various files are given below. Note that most of the files are only used for special purposes and they are normally not required. Some of the files are output files. The program can produce many of the input files. For simpler cases all the necessary input files can be generated by the program.

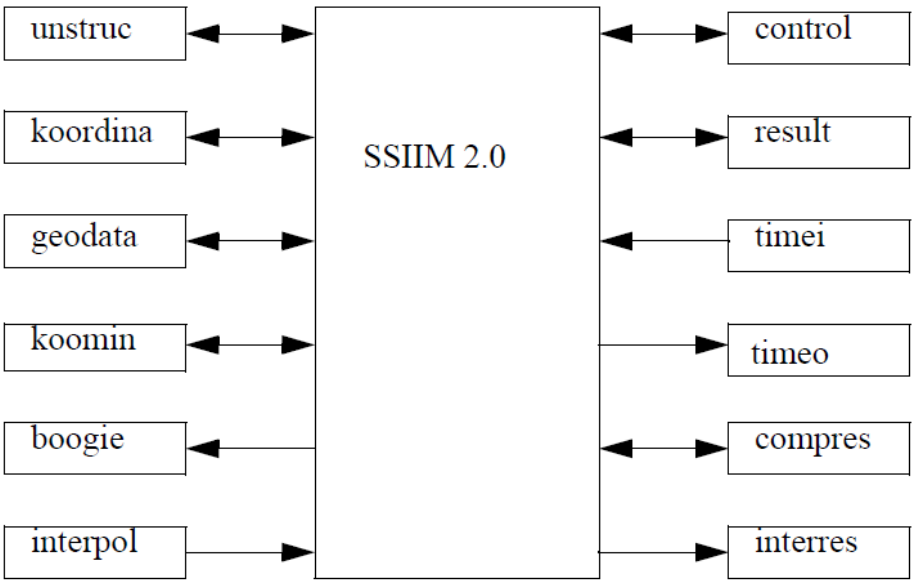


Note that the names of the files can not be changed. The best way to run different simulations is therefore to create a sub-directory for each case.

The two main input files are the *control* file and the *koordina* file for SSIIM 1. The *koordina* file contain the grid geometry. The *control* file contain many of the other parameters. The files have to be present when the program starts. If not, a dialog box will emerge and the user is prompted for the main parameters. The program then generates default files. The *control* file can then be edited afterwards, using a standard editor. The *koordina* file may also be generated by a spreadsheet.

For SSIIM 2, the *unstruc* file contains the grid and water discharges. As it can only be produced by SSIIM 2, it is not necessary to be present when the program starts. SSIIM 2 also need the *control* file,

but default values will be used if it is not present at the start of the calculation. The *control* file for SSIIM 1 and SSIIM 2 are similar, and much of the content is the same for the two versions. However, there are some data sets that are unique to SSIIM 1 or SSIIM 2.



In the following, each file is described.

5.2 The *boogie* file

This is a file that shows a print-out of intermediate results from the calculations. It also shows parameters as average water velocity, shear stress and water depth in the initialisation. Trap efficiency and sediment grain size distribution is also written here. If errors occur, an explanation is also often written to this file before the program stops.

The option *D* on the *F 1* data set will give additional print-out to the file.

Initially in the file it is written how much memory that is occupied by the arrays that are dynamically allocated. To estimate the total recommended memory requirement for SSIIM, add the size of the SSIIM executable to this value.

For SSIIM 1, a table then follows, which shows the cross-sectional area, hydraulic radius, average velocity and water level at the cross-sections that have been used for initializing the water surface. If the option *D* on the *F 1* data set is used, this information is written for all the cross-sections additionally. Then a table of waterlevels for all cross-sections follows. An example is given below:

Loop1,iter,area,radius,velocity,waterlevel: 12 1.002389e+00 1.002389e+00 9.976163e-01 1.002390e+00

Loop1,iter,area,radius,velocity,waterlevel: 11 1.001588e+00 1.001588e+00 9.984146e-01 1.001589e+00
Waterlevel = 1.000398 meters for cross-section i = 10
Waterlevel = 1.000797 meters for cross-section i = 9
Waterlevel = 1.001195 meters for cross-section i = 8

If the *MB-flow* module is used, the residual norms are written. Then follows a sequence of two lines for each iteration of *MB-flow*. An example with four iterations is shown below:

Iter: 5, Resid: 1.69e-05 4.10e-06 2.73e-05 1.17e-04 1.38e-02 1.13e-02
Cont: 9.23e-08, DefMax: 1.65e-03, U,V,W(96,7,20): 6.40e-01 -5.14e-03 5.76e-02
Iter: 6, Resid: 1.62e-05 3.85e-06 2.62e-05 1.10e-04 1.31e-02 1.08e-02
Cont: 9.23e-08, DefMax: 1.56e-03, U,V,W(96,7,20): 6.40e-01 -5.14e-03 5.76e-02
Iter: 7, Resid: 1.57e-05 3.65e-06 2.50e-05 1.04e-04 1.25e-02 1.03e-02
Cont: 9.23e-08, DefMax: 1.48e-03, U,V,W(96,7,20): 6.40e-01 -5.14e-03 5.76e-02
Iter: 8, Resid: 1.51e-05 3.46e-06 2.38e-05 9.86e-05 1.18e-02 9.77e-03
Cont: 9.23e-08, DefMax: 1.41e-03, U,V,W(96,7,20): 6.40e-01 -5.14e-03 5.76e-02

The first line has the word *Iter* at first. Then an integer follows, which shows the number of the iteration. In the example above this runs from iteration number 5 to 9. Then the residuals for the six equations are shown. The x,y and z velocity equations are first, then the pressure equation and the k and e equation follow. All these must be under 10-3 before the solution has converged.

The second line starts with the word *Cont*. Then a floating point value is shown. This is the sum of all the water inflow and outflow in the geometry. This should be a very low value, typically under 10-7. If a larger value is given, check the boundary conditions. Then the word *DefMax* is written. The residual for the cell with largest water continuity defect is then written. The indexes for this cell are then written, with the velocities in the three directions for this cell. In iteration 9 for the example above, the maximum water continuity defect was 1.41e-3 kg/s for cell i=96, j=7, k=20. The velocity in the x-direction for this cell was 0.64 m/s, the velocity in the y direction was -5.14 mm/s and the velocity in the vertical direction was 5.76 cm/s.

5.3 The *control* file

The *control* file gives most of the parameters the model needs. The main parameters are the size of the arrays used for the program. To generate the water surface it is necessary to know a downstream water level, together with the water discharge and the Manning-Strickler's friction factor. These parameters are given on the *G 1* and the *W 1* data set in the *control* file. If the *control* file does not exist, the user is prompted for these parameters in a dialog box. The user can then later choose Write *control* in the *File* option of the main menu, and get a *control* file written to the disk (as *control.new*). This can then be edited according to the user's needs. Note that only the most used parameters are written to the *control.new* file.

During the water flow calculations there are several parameters that can be varied. These parameters

affect the accuracy and the convergence of the solution. Some of the parameters can be modified while the water flow field is being calculated. A dialog box with the parameters is invoked by choosing Waterflow parameters from the Input Editor choice in the main menu.

The *control* file contains most of the other data necessary for the program. SSIIM reads each character of the file one by one, and stops if a capital letter is encountered. Then a data set is read, depending on the letter. A data set is here defined as one or more numbers or letters that the program uses. This can for example be the water discharge, or the Manning-Strickler's friction coefficient. It is possible to use lower-case letters between the data sets, and it is possible to have more than one data set on each line. Not all data sets are required, but some are. Default values are given when a non-required data set is missing. SSIIM checks the data sets in the *control* file to a certain degree, and if an error is found, a message is written to the boogie file and the program is terminated. Note that if more than one numbers are needed on a data set, these are separated by a space, and not by any other character.

Important note: The *F* and *G* data sets should be given before any other data sets. These data sets should also be ordered according to their number. This is because the data may be checked against the size of the grid.

In the following the data sets for the *control* file is described:

5.3.1 The *F* data sets

F 1 Debugging option. If the character that follows is a *D*, one will get a more extensive printout to the boogie file. If the character is a *C*, the coefficients in the discretized equations will be printed to the *boogie* file.

For SSIIM 1, if the character is *Q*, then the program will allow a grid with negative areas. Otherwise, the program will stop when negative areas occur. The *Q* option can be useful when making a complex grid.

If the character is a *P*, then time-stamps are written to the boogie file from different parts of the program. The purpose is to find parts of the program where improvements can be made in the parallelization.

If the character is an *A*, then the grid is checked for possible errors, and error messages are written to the *boogie* file.

F 2 Automatic execution possibility. Some parts of the program will be executed directly after the initialisation if a character is placed in this field. The modules will be executed in the order they are given. The possibilities are:

R	Read the result file
I	Initialize sediment concentration computation
S	Calculate sediment concentration
W	Start the water flow computation
U	Read the unstruc file (**only SSIIM 2**)
X	Read the XCYC file (**only SSIIM 1**)
Q	Compute water quality (**SSIIM 1**)
C	Compute water quality (**SSIIM 2**)

E Write the results from the water quality computation (**SSIIM 2 only**)
O Read the results from the water quality computation (**SSIIM 2 only**)
A End the program and exit (**SSIIM 1**)
X End the program and exit (**SSIIM 2**)
M Write the result file
H Write the unstruc file (**SSIIM 2**)
Y Regenerate the grid (**SSIIM 2**)
V Interpolate the bed levels from the *geodata* file (**SSIIM 2**)
K (**SSIIM 2**) Compute bed roughness from the *geodata* file and write *bedrough.new* file

Example 1 : *F 2 WISA*

The program will first compute the water flow, then compute the sediment flow and then exit. This is for SSIIM 1.

Example 2: *F 2 URIS*

The program will first read the *unstruc* file, and then read an initial water flow field from the *result* file. Then the sediment concentration field is initialized and the sediment transport is computed. This combination is often used for time-dependent morphological computations. The *unstruc* file is only read in SSIIM 2. For SSIIM 1, the *U* is omitted.

Note that there must only be spaces between the number 2 and the letters on the data sets. If tabs are used, the letters may not be read.

F 4 Relaxation factor for second order interpolation of bed concentration, maximum iterations for concentration calculations and convergence criteria for suspended sediment calculation. The convergence criteria is given as allowable flux deficit as part of inflowing sediments.

Note that this data set has changed from SSIIM version 1.1

Defaults: relaxation: 0.5, iterations: 500, convergence criteria: 0.01.

F 6 Coefficients for formula for bed concentration. Default is van Rijn's coefficients: 0.015, 1.5 and 0.3. If one uses this option, the sediment transport formula given in dataset *F 10* must be *R*, which means that van Rijn's formula is used. This is the default formula.

F 7 Run options. read 10 characters. If the following capital letters are included this will mean:

D: Double the number of grid cells in streamwise direction in comparison to what is given in the koordina file. Each cell is divided in two equal parts. When this option is used for the whole geometry, the number of grid lines in the streamwise direction (on the G 1 data set) must be multiplied with 2 and 1 must be subtracted. **SSIIM 1 only**.
J: Double the number of grid cells in the lateral direction. The same procedure for the lines in the lateral direction (*G 1* data set) is required. **SSIIM 1 only.**
I: Inflowing velocities in the y-direction are set to zero. **SSIIM 1 only**.

A: Diffusion for sediment calculations in non-vertical direction is set to zero. SSIIM 1 only.
B: Correction for sloping bed is used when calculating bed sediment concentration.
V: 90 degree turning of the plot seen from above (map). **Only SSIIM 1 for OS/2**.
Z: Vertical distribution of inflowing sediment is uniform. **SSIIM 1 only**.
E: Activate a routine that changes the flux of a grid side if a_p=0.
P: Use porosity calculation and the porosity file. **SSIIM 1 only**.

Note that there must only be spaces between the number 2 and the letters on the data sets. If tabs are used, the letters will not be read.

F 9 **SSIIM 1 only**. Factor that is used to change the turbulent viscosity of the inflowing water. The factor is proportional to the turbulent viscosity. Default: 1.0.

F 10 This data set should not be used any more. Use the *F 83* data set instead.

F 11 Density of sediments and Shield's coefficient of critical bed shear for movement of a sediment particle.

Default: *F 11 2.65 0.047* (SSIIM 1) and *F 11 2.65 -0.047* (SSIIM2).

If a negative Shield's coefficient is given, the program will calculate it according to a parameterization of the original curve.

F 12 Schmidt's coefficient, which is a correction factor for deviation between the turbulent diffusivity and the eddy-viscosity. The factor will affect both the water velocity and the sediment concentration computations. Default: 1.0

If multiple sediment sizes are to be modelled, it is possible to give multiple Schmidt numbers. Example for three sediment sizes:

Example: *F 12 1.0 1.2 1.3*

F 15 An integer giving a choice between several algorithms for wall laws. The choices are different in SSIIM 1 and SSIIM 2.

SSIIM 1: If the value is 1 and there are two walls in a cell, only the closest (usually the bed) will be used. If the integer is 0, both walls will be used. Note that the 1 option will only work with the k-epsilon model. If the integer 3 is specified, wall shear will be used in the source terms of the Navier-Stokes equations, and zero gradients used for k and epsilon on the side walls. If the integer is 4, an algorithm similar to option 3 is used, but only if the cell is below a level equal to the roughness height. Above this height, normal wall functions will be used for all variables. If the integer is 5, smooth wall laws will be used. If the integer is 11, a rough wall law formulation by Rodi (1980) will be used for k.

SSIIM 2: Zero is normal rough wall laws. A value of 8 will use a combination of rough and smooth wall laws if the roughness is small. A value of 19 will use smooth wall laws on the sides and rough on the bed.

Default: *F 15 0*

F 16 Roughness coefficient which is used on the side walls and the bed. If not set, the coefficient is calculated from the Manning-Strickler's friction coefficient (van Rijn, 1982). Values in the *bedrough* file overrides this value for the bed cells.

F 18 Density current source. A float is read, and if it is above 10^{-6}, the sediment density term in the Navier-Stokes equation is added. The float is multiplied with the density term, so a value of 1.0 is recommended when this term is needed. Default 0.0 (the term is not used). Note that this option has not yet been tested.

F 20 **SSIIM 1 only**. Repeated calculation option. An integer is read, and the calculation sequence on the F 2 data set will be repeated this many times. Note that the graphical view of the bed level changes (only OS/2 version) will only appear on the last iteration when sediment calculations are done. Also note that if a *result* file is read in the *F2* data set, it is only read during the first iteration.

F 21 Relaxation coefficient for the Rhie and Chow interpolation. Normally a value between 0.0 and 1.0 is used. When 0.0 is used the Rhie and Chow interpolation will have no effect. When 1.0 is used the Rhie and Chow interpolation will be used normally. Default 1.0.

F 24 Turbulence model. An integer is read, which corresponds to the following models:

0: standard k-ε model (default)
1: k- ε model with some RNG extensions
3: local k- ε model based on water velocity
4: constant isotropic eddy-viscosity model, value given on *F 72* data set. Only SSIIM 2
5: local k-ε model based on wind shear
6: constant non-istotropic eddy-viscosity model, vertical and horizontal values given on the F 77 data set
7: eddy viscosity = 0.11 * depth * shear velocity (Keefer, 1971)
10: zero-equation used in shallow areas only, k- ε elsewhere. Only SSIIM 2
14: Spalart-Almaras model, only for SSIIM1, not fully implemented
15: K-omega model with Wilcox's wall laws, only for SSIIM 1, not tested
16: K-omega model with k-ε wall laws, only for SSIIM 1.

Note that not all models are implemented in both SSIIM versions.

F 25 Porosity parameters. Four floats and one integer are read. The first float is the minimum porosity. The second float is a relaxation factor for the porosity computation. The third and fourth floats are roughness values used in the porosity computation. The last number, the integer, is an index giving which algorithm to use for the computation of the diameter in the equation.

Default: *F 25 0.35 2.0 0.5 0.8 5*

F 26 Fraction of compacted sediments in bed deposits. Or 1.0-water content of sediments at bed.

Default: F 26 0.5 (50 % water)

F 33 Transient water flow parameters. A float and an integer is read. The float is the time step in seconds. The integer is the number of inner iterations for each iteration. Transient terms will be included in the equations if this data set is present.

F 36 Options for computation of the vertical elevation of the water surface. Several algorithms are available. Some are described by Olsen (2015).

An integer is read. The most used algorithms is based on the computed pressure field. This algorithm is used if the integer is 2. The cell given on the *G 6* data set will be kept fixed as a reference level. A number of other options are also possible, depending on which SSIIM version is used-

For SSIIM 1:

If the integer is 1, the gravity will be included in the solution of the Navier-Stokes equations, and the water level will be computed based on the computed water deficit/surplus in the cells close to the water surface. Olsen (2015) describes this as a CGA method (Continuity, Gravity and Adaptive grid). This algorithm is very unstable, especially the SSIIM 1 version. A very short time step needs to be used. The algorithm is only used when computing coefficient of discharge for a spillway, or flood waves with steep fronts.

For SSIIM 2:

More algorithms can be used: *F 36 3*: the initial water surface is moved up/down equally in all cells according to downstream changes in water surface specified in the timei file.

F 36 7: the water surface elevation is computed solving a partial differential equation for the local slope as a function of the pressure gradients to the four neighbour cells. This is described as the IPDA (Implicit Pressure Difference with Adaptive grid) method by Olsen (2015). Note that some variations of the IPDA algorithm are invoked by the F 278 data set.

The IDWA (Impicit Diffusive Wave, Adaptive grid) method (Olsen 2015) is invoked by *F 36 9.*

The CGA method in SSIIM 2 is invoked by *F 36 15*. One of the example cases on the SSIIM web page uses this option.

Default: *F 36 0* (no change in the water surface elevation)

F 37 Transient sediment computation. An integer is read. If this is 1, the transient sediment computation (TSC) algorithms will be used. This option is always used when doing time-dependent computations of sediment transport, and always when computing changes in bed levels. If the integer is 2, then a different algorithm is used for the bed cells, where the sediment concentration formula is converted into an entrainment rate. This can give slightly smaller bed movements where the bed sediment concentration is not in equilibrium.

Default: *F 37 0*

SSIIM 2 only: If the integer is 3, then an algorithm is invoked where more than two bed layers

can be used. (active + inactive layer = 2 layers for *F 37 1* and *2*).

F 38 Residual limit for when warning messages are written to the boogie file.

Default: *F 38 107*

F 40 Turbidity current parameter. If this is unity the extra term in the Navier-Stokes Equation are taken in that takes into account the effect of gravitational forces on water that have higher density because of high sediment concentration. If this is above 0.001, the term is still incorporated but relaxed with the factor on the data set. Default 0.0.

F 41 **SSIIM 2 only**. Sediment thickness in meters. Default: 10 meters.

F 42 **SSIIM 2 only**. Level of non-erodible material. This data set can be used instead of the *koomin* file.

F 47 Bed interpolation parameter in meters. One float is read, which is used in the bed interpolation routine that are called from the *Grid Editor*. If the points given in the *geodata* file are located a horizontal distance under the interpolation limit, than the interpolation routine will use the exact value of the *geodata* point instead of interpolating from surrounding points. Default: 0.05 m.

F 48 Parameter for print-out of special files and interpolation of results. An integer is read. If 0, then a normal *result* file will be written when this routine is invoked. If higher values are given, the program will not write the *result* file. It will search for the *interpol* file and use this file to write other files. If the integer is between 1 and 4 an *interres* file is written. If the value on the *F 48* data set is 4, the bed levels will be written to the *interres* file. If 2, the velocities, k and ε will be written to the file. If 3, then water quality parameters will be written. If the integer is 5, the *habitat* file will be written.

Default 0. See Chapter 5.12 for more details.

SSIIM 1 only: If the integer is 19, a time will also be read from the *interpol* file. The print-out to the *interres* file will then only happen at this time. If the integer is 9, a 2D plan view Tecplot file will be written. If the integer is 20, a file called *sumforce* is written. The file contains the pressure forces at the upstream and downstream boundary, together with bed shear forces in a longitudinal profile.

SSIIM 2 only: If the integer is 5, the water velocities in the surface cell is written to the *interres* file. If the integer is 14, the value of the average velocity times the depth is written to the *interres* file. If the integer is 10, a three-dimensional ParaView file is written. If the integer is 12, a two-dimensional ParaView file is written from the cross-section defined in the *interpol* file, with the water velocities normal to the surface. If the integer is 18, 2D Tecplot files are written for both the coarse and the nested grid. If the integer is 19, 2D Paraview files are written for both the coarse and the nested grid.

The options 88, 89, 91 and 92 will do the same as options 8, 9, 11 and 12, respectively, but the *result* and *bedres* files will not be written simultaneously.

F 50 Number of water quality constituents. Default F 50 0.

F 51 Coriolis parameter.

Example: *F 51 0.0001263* (lakes in South Norway)

F 52 Wind forces on the surface of the lake. Three floats are read. The first float is the magnitude of the wind speed in meters/sec.10 meters above the water level. The second and third floats are components of the unity vector in the *x* and *y* direction. Note that the vector sum must be unity.

Example: *F 52 4.0 -1.0 0.0*

Note for time-varying wind, the values in the *timei* file overrides the values on this data set.

F 53 Print iterations. Four integers are read, which gives the interval for when printout to files are done. The first integer applies to the residual printout to the *boogie* file. The second integer applies to writing the *result* file. The third integer applies to writing data to the *forcelog* file. The fourth integer applies to when data is written to the *timeo* file.

Default: *F 53 100 100 1 1*

This means that for example the *result* file is written each 100th iteration.

F 54 A float is read, which is a limit for the residual during the transient calculation. When the maximum residual goes below this value, the inner iterations end, and a new time step starts. This is recommended when doing transient computations. Default 10^{-7}

F 56 Sand slide algorithm. An integer and a float is read. The float is tan(angle of repose). The integer is the number of iterations the algorithm will go through the whole grid. If 200 is chosen, a particular algorithm is used which has given better results than the other ones.

Default: *F 56 0 1.0* (not used)

Typical values if used: *F 56 200 0.62*

Note that the angle of repose for the sediments is lower for sediments submerged in water than in air. The algorithm does not work properly for more than one sediment size.

F 58 **SSIIM 1 only**. Parameters for the Transient Free Surface (TFS) algorithm. The TFS algorithm is used when including *F 36 1* in the *control* file. Four integers and six floats are read:

F 58 i1 i2 i3 i4 f1 f2 f3 f4 f5 f6

Default: *F 58 1 0 0 1 0.02 2.0 2.0 0.0 1.0 0.0*

i1: If this integer is 1, the transient terms are included in the equations. If it is zero, the transient terms are not included

i2: If the integer is 1, the pressure will always be positive

i3: If the integer is 1, the side walls will not move vertically

i4: If the integer is 1, an upwind algorithm is used to transfer the water level movement from the center of the cell to the corners. If the integer is zero, the movement will be equal in all directions.

f1: Parameter in the upwind algorithm for transferring the water level movements from the center of the cell to the corner. If the parameter is zero, all the movement will take place in the downstream direction. A very large parameter will give equal movement in all directions.

f2: Parameter to dampen the water movement at the walls. If the parameter is 2.0, there will be no damping. A value of 1.0 will dampen the movement to half the non-dampened value. A value of 0.0 will dampen the movement completely, so no movement will take place at the wall.

f3: Parameter to dampen the water movement at obstructions. The numbers are the same as for parameter f2.

f4: When the water level moves in a time step, the water surface will get a vertical velocity, W. An algorithm is used, where the velocity in the top cell, w, is affected by W, using the following formula: w = f4 W + (1-f4) w.

f5: Parameter for including the acceleration of the water movement in the vertical component of the Navier-Stokes equation. If it is 1.0, the full acceleration term is included. If the parameter is zero, the acceleration term is not included. A value between 0.0 and 1.0 will take the term into account, multiplied with the parameter.

f6: A factor for smoothing the water levels. If it is zero, no smoothing will be used. A higher, positive value will give more smoothing.

F 59 Number of iterations in the Gauss-Seidel procedure. This is an integer which will affect the convergence and speed of the program. A lower value will increase the number of iterations pr. time, while slowing the relative convergence pr. iteration. For some cases, a lower value has given decreased computational time. Note that if the TDMA solver (*K 10* data set) is used, then the *F 59* data set will have no effect. Default: 10.

F 60 Correction of van Rijn's formula for distance from the center of the bed cell to the bed. The data set is used to invoke inclusion of the extrapolation of the Hunter-Rouse sediment distribution when the vertical height of the center of the bed cell is different from what van Rijn subscribed.

Default: *F 60 0 0* (no use of the extrapolation)
Example: *F 60 1 0* (the extrapolation is used)

F 62 Integer to invoke time-dependent calculation of water quality parameters, if 1.

Default: *F 62 0*

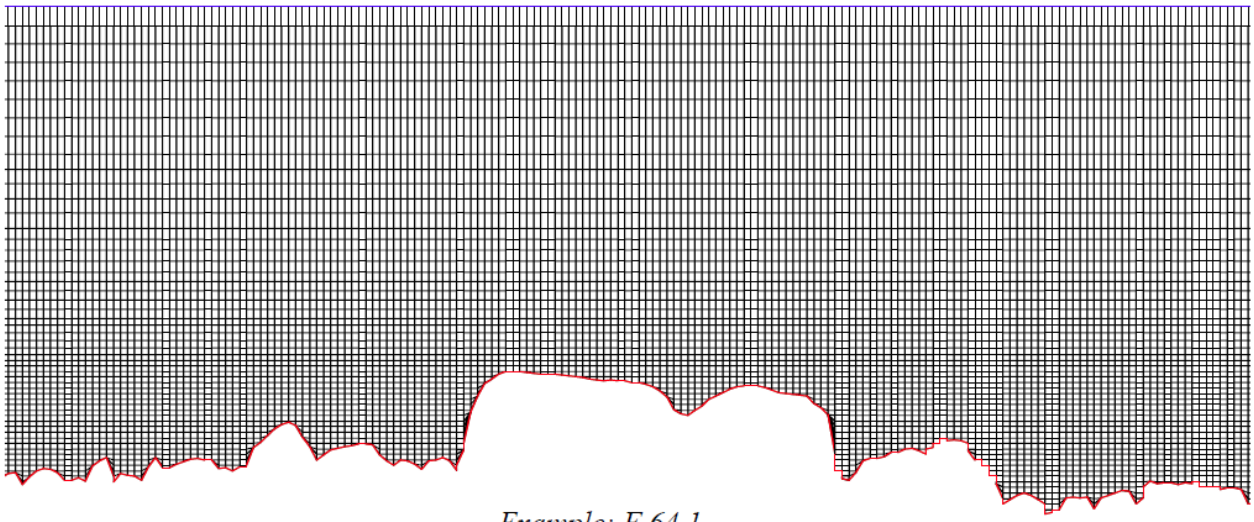
F 63 Second-order upwind scheme for water quality constituents if the integer 1 follows.

Default: *F 63 0*

F 64 SSIIM 2 only. Choice of algorithm to generate the grid lines in the longitudinal and lateral direction.

Default: *F 64 11*

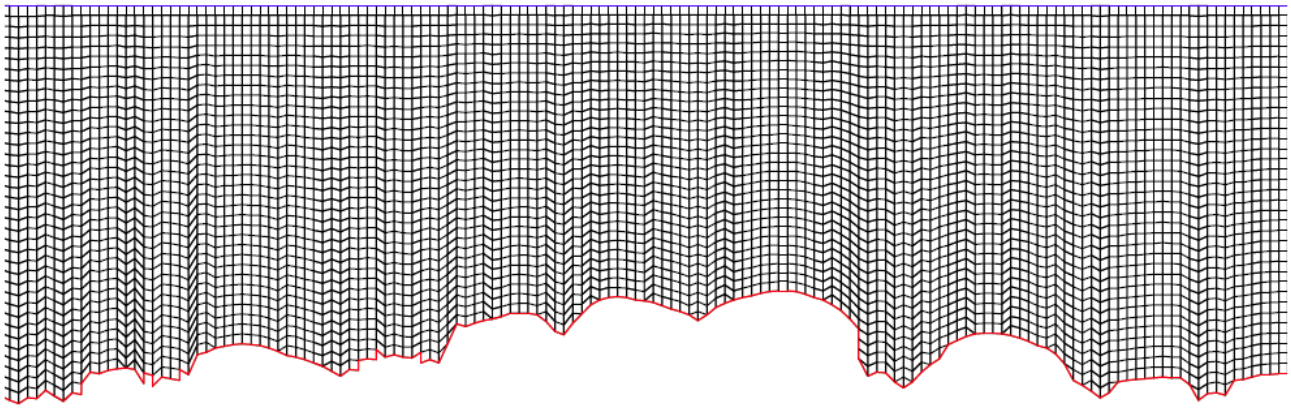
An integer is read. If it is 0, completely horizontal grid lines will be generated. This is typically used when modelling lakes, especially with density gradients.



Example: F 64 1

The F 64 1 option will also create horizontal grid lines, but the bed cells will not be horizontal. Tetrahedral cells and hexahedral cells with non-horizontal lines will be used along the bed.

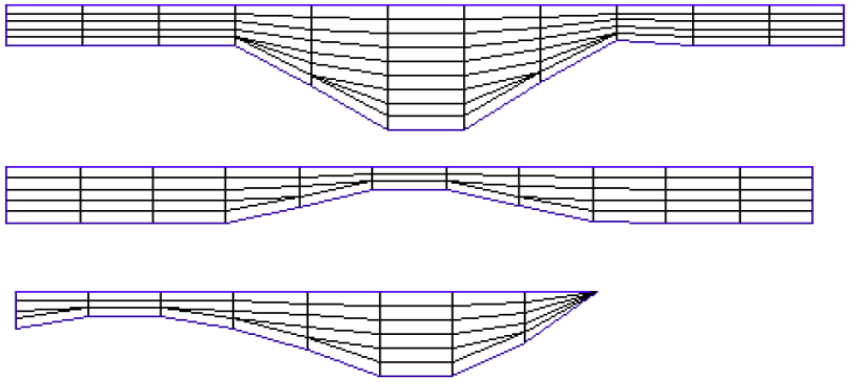
The F 64 2 option will be similar to *F 64 1*, but all the non-vertical grid lines may be non-horizontal. An example is shown in the figure below.



Example: F 64 2

For sediment transport computations in rivers, the most tested option is *F 64 11*. This will give a body-fitted grid with priority to hexahedral cells close to the bed. The hexahedral cells will give superior performance compared to tetrahedral cells. Since most of the sediment is transported close to the bed, it is important that the bed cells are hexahedral in sediment computations.

Example:
F 64 11



The option 13 is similar to 11, but has different generation criteria for wetting and drying. The two values on the F 94 data set is then used. If the F 64 13 data set is used, then the cells will be generated initially just like using the F 64 11 option. However, cells will not be generated in areas that were dry in the previous iteration, unless the cell depths are above 0.0 meters. The value 0.0 meters can be changed by giving a different number on the F 162 data set.

See also Chapter 4.3.2 for generation of grids.

F 65 SSIIM 2 only. Grid size for the unstructured grid. SSIIM 2 has to allocate the arrays before the grid is read. Because it is possible to expand the grid after it is read, it is necessary to give the grid array sizes in the input file.

Five integers are read. The first integer is the maximum number of grid cells in the grid. The second integer is the maximum number of surfaces in the grid. The third integer is the maximum number of grid corner points. The fourth integer is the maximum number of surfaces in connection between blocks. The sixth integer is the maximum number of connection points, used in the Grid Editor.

Default: *F 65 50000 80000 50000 10000 1000*

If the grid has been made, and the grid size will not increase later, it is possible to read the size in the unstruc file, and modify the F 65 data set so that the program does not allocate more memory than necessary.

F 67 SSIIM 2 only. Temperature calculation with feedback from water density on the water flow calculation if it the integer 1 follows.

Default: *F 67 0*

F 68 Parameter for choice of water flow computation. An integer is read.

Default: *F 68 0*

If the parameter is 2, the transient sediment computation will not re-compute the water flow field after an update of the bed. This means a quasi-steady situation is modelled.

For SSIIM 2: If the parameter is 1, the three-dimensional calculation of the water flow will be done using the hydrostatic pressure assumption. This means that the Navier-Stokes solutions will not be solved in the vertical direction, and vertical velocities will be found by the continuity equation. This option causes an extra grid block to be made. The extra block is the last block and is a depth-averaged version of the whole grid. Note that this parameter have to be the same when calculations are done as when the grid was created.

F 70 **SSIIM 2 only**. Wall laws removal option. An integer is read. If 1, the wall laws will be removed from the side surfaces. If 2, the wall laws will be removed from the side and the bed surfaces.

Default: *F 70 0*

F 71 Turbulence decrease because of density stratification. An integer is read. If 1, the turbulent eddy-viscosity is decrease according to the Richardson number and the procedure given by Rodi (1980).

Default: *F 71 0*

F 72 Minimum turbulent eddy-viscosity. A float is read. The eddy-viscosity for water flow, turbulent kinetic energy and water quality constituent calculations will not be decreased below this value.

Default: *F 72 0.001*

F 73 Choice of wind friction formula. This formula gives the shear stress of the water surface as a function of the wind. The options are:

0: van Dorn (1953), c_D = 1.0x10-3 under 5.6 m/s, increases over 5.6 m/s
1: Bengtsson (1973), c_D = 1.1x10-3
2: Wu (1969), three non-continous bands of c_D as a function of wind speed

Default: *F 73 0*

F 76 **SSIIM 2 only**. Turbulence reduction factors. Three floats are read. The two first floats are multiplied with the eddy-viscosity in the horizontal and the vertical direction respectively, thereby reducing and possibly creating a non-isotropic eddy-viscosity. The third float is related to the decreased eddy-viscosity because of density stratification. If it is zero, the eddy-viscosity decrease factor will be applied isotropically. If it is unity, the factor will only be applied to the vertical eddy-viscosity. For

values between zero and unity, the factor will partly be applied only vertically and partly isotropically, creating a more or less non-isotropic eddy-viscosity.

Default: *F 76 1.0 1.0 0.0*

F 77 **SSIIM 2 only**. Constant non-isotropic turbulent eddy-viscosity. Two floats are read, the horizontal and the vertical eddy-viscosity. Note that the *F 24* data set must have the parameter 6 for this data set to be used.

Default: *F 77 1.0 1.0*

F 78 Bed load vector parameters. An integer and a float is read. The bed load on a transverse sloping bed may not move in the direction of the water velocity close to the bed. If the integer is 1, an algorithm taking this into account is used. Note that this is fairly untested yet, especially for SSIIM 2.

In SSIIM 2, an integer 10 can be given as the first integer. The algorithm will then use the average sediment diameter instead of the diameter of each size. In SSIIM 2, this is the only option for using the algorithm with multiple sediment sizes.

F 81 Number of time steps in the *timei* file. An integer is read.

Default: *F 81 200*

F 82 Parameters to decrease the eddy-viscosity as a function of the water density gradients and the Richardson number. In the formula, the alpha and beta are constants. This data set gives the alpha and the beta for the velocity and the temperature/other constituents. Four floats are read.

Default: *F 82 -0.5 10.0 -1.5 3.33*

F 83 Coefficients in van Rijn's formula for bed load sediment transport. Four floats are read.

Default: *F 83 0.053 2.1 0.3 1.5*

F 84 Flag to indicate the sediment transport formula. An integer is read:

0: Suspended load formula by van Rijn
1: Bed load formula by van Rijn
2: Both suspended and bed load formulas by van Rjin
3: Wu's formula
5: Meyer-Peter and Mullers formula (SSIIM 2 only)

Default: *F 84 0*

F 85 **SSIIM 2 only**. Flag indicating that the computation should not stop if water continuity is not satisfied. This is invoked if 1 is given.

Default: *F 85 0* (program will stop if continuity is not satisfied)

F 86 **SSIIM 2 only**. Minimum grid corner height. This is used to prevent very small grid cell heights. If the corner grid cell is lower than this value, it is set to zero. Note that this only works for the *F 64 5/11/13* options.

Default: *F 86 0.001* (1 mm)

This information can alternatively be given on the *F 94* data set. Then the parameter on the *F 86* data set will be equivalent to the second data set on the *F 94* data set. The first parameter on the *F 94* data set will be set to 1/4 of the *F 86* value.

F 87 **SSIIM 2 only**. Parameter for number of grid cells, n, in the vertical direction as a function of water depth, y. The value is the p parameter in the following formula:

The *nmax* number is the third integer on the G 1 data set.

Default: *F 87 0.6*

F 90 Roughness option. An integer is read, giving several options how the roughness in the wall laws should be calculated:

0: The value on the W 1 or F 16 data set is used.
1: The bedrough file is used (SSIIM 1 only)
2: The roughness is calculated from the bed grain size distribution (d90)
3: The roughness is calculated from d90 and the bed form height
4: Same as 3, but the critical shear stress for sediment movement is reduced so that only the grain roughness effect is taken into account.

Default: *F 90 0*

F 92 **SSIIM 2 only**. Algorithms to reduce velocity in cells with small depths. An integer is read:

1: Wall laws are used in more than one cell
2: A drag formula is used for velocities where the roughness is higher than the cells

Default: *F 92 0* (Algorithm is not invoked)

F 94 **SSIIM 2 only**. Minimum grid corner height and maximum grid corner height for generation of one cell. Two floats are read. The first float is used to prevent very small grid cell heights. If the corner grid cell is lower than this value, it is set to zero. The second float gives the depth of having only one cell in the vertical direction -> 2D calculation. Note that this only works for the F 64 11 and 13 options.

Example: *F 94 0.001 0.01* (default)

Grid cells under 1 mm will not be generated, and all cells under 1 cm will be 2D.

F 99 **SSIIM 2 only**. Integer to determine how often the grid is regenerated for time-dependent sediment flow calculations with moveable bed.

Default: *F 99 1*

Example: *F 99 10*

The grid will only be regenerated for every 10th time step.

Sometimes it is necessary to use *F 99 1* to be able to read the *bedres* file together with the other files, when starting from a previous computation.

F 100 **SSIIM 1 only**. Integer to determine if the second term of the Boussinesq equation is included when computing the Reynolds shear stress. If the integer is 1, it is included.

Default: *F 100 0*

F 102 **SSIIM 2 only**. Integer to invoke an algorithm to change the shape of the grid cells close to the boundary. If the integer is 1, the algorithm is included. This algorithm is recommended for wetting/drying computations.

Default: F 102 0

F 104 **SSIIM 2 only**. Integer invoking an algorithm to prevent crashes when a single cell is formed. The algorithm is only invoked if the integer is above zero. The algorithm will add a value to the a_p coefficient in the pressure-correction equation of SIMPLE. This will only be used in the cells that have no neighbour cells. The value added is the integer multiplied with the volume of the cell.

Default: *F 104 0*

F 105 **SSIIM 2 only**. An integer is read, giving the number of iterations between each update of the water surface elevation for time-dependent calculations.

Default: *F 105 10*

F 106 A float is read, giving the thickness of the upper active sediment layer. The default value is equal to the maximum sediment grain size diameter on the *S* data sets.

F 107 **SSIIM 1 only**. Upstream water elevation in the TFS algorithm. An integer is read. If it is 1, the TFS algorithm will compute the water level of the most upstream cross-section using a 1D backwater algorithm, from the second most upstream cross-section. This is done automatically if *G 7* data sets are not used, so then this data set is not necessary.

Default: *F 107 0*

F 108 **SSIIM 1 only**. A minimum water depth used by the TFS algorithm.

Default: *F 108 0.02*

F 109 Parameters in Brook's formula for reduction of the critical sediment particle shear stress when the bed slopes.

Default: *F 109 1.23 0.78 0.2*

The two first floats are the inverse of tan(θ) for uphill and downhill slopes, where θ is a kind of angle of repose for the sediments. θ is actually an empirical parameter based on flume studies. The third float is a minimum value for the reduction factor.

F 110 SSIIM 2 only. Parameters for limiting the effect of the Hunter-Rouse extrapolation for sediment concentration computed in a reference level different from what van Rijn subscribed. The parameter will only have effect when used with the *F 60* data set.

Default: *F 110 2.0 0.01*

F 111 BEDDLL parameter. An integer is read. If it is 1, the sediment transport algorithms in the *beddll.dll* file are used instead of the default algorithms.

F 112 SSIIM 2 only. An integer is read. If it is 1, the program will regenerate the grid automatically right after it has read the *unstruc* file. The regeneration will be made from the water levels given in the *koordina* file. The option is used when computing wetting/drying in a situation where the initial water level is lower than what it will be later. In other words, the program is started with dry cells. The program needs to know the grid layout of the areas that will be wetted, so the *unstruc* file needs to cover the whole geometry. If the initial computational domain will expand horizontally at a later time, than the initial water level can be given in the *koordina* file, and the program will start with a grid based on this.

Note that if the *G 6* option is used in this case, the indexes refer to the grid in the original *unstruc* file, and not on the regeneration after the *koordina* file is used. Also, the inflow/outflow specification is done on the grid in the original *unstruc* file.

One of the most common problems for new SSIIM 2 users has been that they write the *unstruc* file with dry cells. The latest versions of SSIIM 2 will therefore not allow the *Grid Editor* or the *Discharge Editor* to open if the *F 112* data set is used in the *control* file.

F 113 SSIIM 2 only. Algorithms to stabilize the solution in very shallow regions close to the side walls. The algorithms use different interpolation algorithms from the center of the cells to the cell surfaces. Different algorithms have been tested, using integers from 1 to 7.

3,4: Using second-order interpolation instead of third-order interpolations for pressure gradients

5: Setting the Rhie and Chow term to zero for 2D cells in shallow areas. Shallow defined as depths below the values given on the first value of the *F 94* data set.

7: Flux-limiter: the extra term from the Rhie and Chow interpolation should not be more than 20 % of the linear interpolation term.

Note that these algorithms are not tested extensively

Default: *F 113 0* (algorithms not used)

F 114 SSIIM 2 only. An integer is read. If it is 9, 10 or 20, special algorithms to compute the pressure gradients are used. This can give a more stable solution where there are very shallow areas inside the main grid. A similar routine is also used on the pressure-correction gradients in the SIMPLE method if the integer is 10.

Default: *F 114 0* (algorithms not used)

F 115 VEGDLL parameter. An integer is read. If it is 1, the algorithms in the *vegdll.dll* file to compute the effect of plants/large stones on the water flow are used instead of the default algorithms.

F 116 SSIIM 2 only. TFSDLL parameter. An integer is read. If it is 1 or 2, the free surface algorithms in the *sfdifdll.dll* file are used instead of the default algorithms. If 1, an implicit procedure is used to find the water surface. If the integer is 2, an explicit procedure is used.

F 125 SSIIM 2 only. TSCDLL parameter. An integer is read. If it is above zero, the transient sediment computation algorithms in the *tsc2dll.dll* file are used instead of the default algorithms.

F 128 SSIIM 2 only. Setting the pressure field to zero in the TSC algorithm to prevent instabilities. An integer, n, is read. The pressure is set to zero for each n'th time step. The algorithm has not been very successful in testing.

F 131 SSIIM 2 only. Cohesive parameters. And integer and a float is read. The integer determines the sediment size. The float is a critical shear stress for erosion of each particle size. Multiple *F 131* data sets are given for multiple sediment sizes. Default: 0.0 for all sizes. Note that this number is only used to determine the critical shear stress for erosion of a particle. It is not used in the sediment transport formulas.

F 132 SSIIM 2 only. Maximum Froude number for update of water surface. A float is read. This is a stabilizing depth-limiter algorithm for the water surface computation. The water level is limited in size so that high Froude numbers do not emerge. The critical Froude number is given on the float. Default: 0.0, meaning the algorithm is not used. Note that this algorithm may introduce unphysical water levels, with corresponding instabilities.

F 133 SSIIM 1 only. Special solver for grids with fairly large porous areas. A float and an integer are read. The float is a porosity limit for when the algorithm is used. The integer is the number of iterations in the algorithm. This algorithm is not fully implemented yet.

F 134 SSIIM 2 only. Number of bed layers. This is used in an algorithm using several sediment layers under the bed. The purpose is to compute for example sediment composition in a delta. This algorithm is not fully implemented yet.

F 138 SSIIM 2 only. Minimum value of the turbulent kinetic energy. A float is read. Default: 10-20.

F 139 SSIIM 2 only. Two floats are read. Minimum values of u+ in the wall laws for the velocity and turbulent kinetic energy.

Default: *K 139 1.0 1.0*

Better stability has been obtained by using higher values than 1.0, for example 3.0.

F 141 SSIIM 2 only. A limiter for epsilon. A float is read. This is the maximum value epsilon will get. Default: 100.0. (Minimum value for epsilon is hard-coded to 10^{-16})

F 142 SSIIM 1 only. Convergence criteria for update of the water surface. A float is read.

Default: *F 142 0.001*.

F 144 Bed form smoothing algorithm. An algorithm is invoked to smooth the bed as a function of the bed form characteristics. An integer and a float is read. The smoothing is used if the integer is above 0. The default value is 0.

F 145 SSIIM 1 only. Integer to invoke the *roughm1.dll* DLL file. In this file, the bed roughness or the vegetation parameters can be modified by the user. The DLL file is used if the integer is above zero.

F 147 SSIIM 2 only. Parameters for use in extrapolation of initial values to newly wetted cells.

Default: *F 147 20 0 1 0.2 1.0 1.0* .

The first integer gives how many iterations the extrapolation algorithm should be used. This should be larger than the number of cells in one direction in the wetted area. The second integer determines which of two interpolation algorithms are used when transferring variables between two grids. The default algorithm (0) uses a linear interpolation based on the vertical elevation of the cells. An alternative algorithm (1) uses the cell indexes. The third integer invokes the part of the algorithm that extrapolates over multiple cells for each wetting situation. The fourth number, a float, gives a relaxation factor for the velocity values. The fifth and sixth number, both floats, give relaxation factors for k and epsilon. During initial testing, we have not found any improvements in the results by using values different than the default.

F 148 SSIIM 2 only. Maximum slope of the water surface. A float is read. If the number is above zero, an algorithm is invoked that prevents the water surface to be steeper than the value given. Default -0.1 (algorithm not used).

F 149 Non-isotropic turbulence parameters. Two floats are read. The first float is multiplied with the isotropic diffusion to produce the vertical diffusion used by the program. The second parameter does the same in the horizontal direction.

Default: *F 149 1.0 1.0*.

F 150 SSIIM 1 only. Option with modified wall laws. Two integers are read. The first integer

modifies the wall laws for high roughness/water depth ratios. Option 1 uses a three-layer model where the middle layer is when the bed form height is higher than the roughness. Option 2 uses a two-layer model where the middle layer is not used. The inner layer is a linear function. Option 0 is the function used previously. The second integer will use a kappa of 0.4 if the integer is 1. If it is zero, it will modify kappa according to the bed concentration, using Einstein's formula.

Default: *F 150 0 0*

This data set is not much tested.

F 151 SSIIM 1 only. Parameters for special algorithms for very shallow flows. An integer and a float is read. The float is the minimum water depth in the grid in meters. The default is 3 % of the average grid cell length. The integer is a choice of combination of different parameters. The algorithms are used if the bed level rises above the minimum water depth. The following options can be used:

A: A sink term in the Navier-Stokes equations are used in the shallow areas
B: The SIMPLE corrections are not used in the shallow areas
C: An algorithm setting a_{nb} to zero in the shallow areas
The options for the integer are:

0: No special algorithms are used (default)
1: A
2: A+B
3: B
4: B+C
5: C

F 154 Smoothing algorithm for the water surface. An integer and a float is read. Smoothing is done if the integer is 1. The smoothing is done by taking the average of the four neighbour values and multiplying this with the float parameter on the data set. Then, (1.0- the parameter) is multiplied with the old value and added. This gives the new value.

In SSIIM 1, the averaging is done on the pressure at the water surface, before the surface changes are done. In SSIIM 2, the averaging is done on the water levels directly.

SSIIM 2 only: If the integer is 3, dry areas will not be smoothed. If the integer is 1, also dry areas will be smoothed. Integers 2 and 4 will give the same as 1 and 3, respectively, but the boundary will also be smoothed.

F 156 SSIIM 2 only. Option to pause the program during a computation. This is used for debugging purposes. An integer is read. The following options are possible:

1. Before the start of regenerating the grid
2. After the regeneration of the grid
3. Before the velocity and flux corrections in the SIMPLE algorithm
4. After the velocity and flux corrections in the SIMPLE algorithm
5. Before interpolating the variables to the new grid
6. After interpolating the variables to the new grid
7. At the end of a time step computing the bed level changes (*F 37 1/2*)

The option can be used in combination of the *Pause* option in the *Compute* menu of the program.

F 159 SSIIM 2 only. Algorithms to improve stability by avoiding grid problems. Five integers are read, for five different algorithms. The algorithms are invoked if the integer is 1, and it is not invoked if the integer is 0. The algorithms are only used when the parameter on the *F 64* data set is equal to 8, 11, 13, 38 or greater than 100.

The first algorithm tries to remove dead-end channels that are only one cell wide. A maximum of 30 cells can be removed.

The second integer invokes different algorithms dealing with the problem of ridges between wet cells. Some algorithms try to give better connection between two neighbour column of cells that are separated by a high ridge. This is done by increasing the water depth. Several algorithms are used with different depths. An integer of 1 sets the depth to 80 % of the first parameter of the F 94 data set. An integer of 2 or 3 sets the water depth to minimum the value of the first parameter on the F 94 data set. An integer of 4 does the same as 1, but uses a value of 200 % of the first F 94 parameter, instead of 80 %. An integer of 3 sets the number of vertical grid lines in the corners between the cells to 1 if one of the corners have a negative depth and the sum of the two corners is smaller than 10 % of the first parameter on the F 94 data set. An integer of 7 does the same thing as 1, but uses 100 % of the second parameter on the F 94 data set instead of 80 % of the first. Other algorithms sets internal walls in the ridges. The integer is then set to 9 or 10.

The third algorithm will try to remove holes in the grid, where there is only one cell with no connections to side neighbours, only with its neighbours below and above. This is in a wetted area, where in 2D, the neighbours exist.

The fourth algorithm will remove single wet cells with only dry neighbours in 2D.

The fifth integer invokes different algorithms to increase the water depth in partially dry cells, by lowering the bed levels. So far, none of these algorithms have been successful. An integer of 1 lowers the bed level to the first value given on the F 94 data set. This also happens if the integer is 2, but then multiple cells in the vertical direction is allowed, also on side walls. If the integer is 3, then the depth is increased so that the bed slope is not above 20 degrees. If the integer is 5, then neighbours are disconnected if the area between them is smaller than a small number.

Default: F 159 1 0 0 1 0

F 160 SSIIM 2 only. Flag to decide which algorithm is used to compute the available sediment at the bed when deciding the limits of sediment concentration. An integer is read. If it is 0, the available sediments will be equal to the bed cell area times the depth of the sediments. If the integer is 1, then also neighbour cells will be included.

Default: F 160 0.

F 162 SSIIM 2 only. Value to determine whether a cell is generated or not in regions where the bed was dry in the previous time step. Default 0.0 meters. The parameter only works in connection with the *F 64 13* option.

F 163 SSIIM 2 only. Flag to decide which algorithms are to be used to limit the movement of the bed. An integer is read. Three options are possible:

0. The bed level will not be allowed to move below the movable bed, but it will be allowed to move above the water surface.

1. The bed level will not be allowed to move above the water surface or below the limit of the movable bed.

2. The bed level may move above the water level or below the limit of the movable bed.

F 164 SSIIM 2 only. Different versions of OpenMP multi-core solvers. An integer is read, specifying the number of the solution algorithm.

F 165 SSIIM 2 only. Grid numbering direction. When the unstructured grid is made, the indexing of the cells start at the lower left corner, or the first point marked in the *Grid Editor*. One integer is read on this data set. If the integer is 1, then the cell indexing will start on the corner diagonal opposite in the block. This is mostly useful for debugging purposes.

Default: *F 165 0*

F 166 SSIIM 2 only. Regeneration of grid after water surface update. An integer is read. If it is 1, then the grid will be regenerated after each time the water surface is updated, also if time-dependent sediment transport is computed. This is usually not done, as the bed changes are normally recomputed more frequently than the water surface changes, and the grid is always regenerated after each bed change.

Default: *F 166 0*

F 168 SSIIM 2 only. Multi-grid solver for the pressure-correction equation. An integer is read, and this is the number of levels in the grid nesting. If the integers is 0, the algorithm is not used. Note that the *K 5* data set also needs to be used to get the algorithms to work.

Default: *F 168 0*

F 169 Hiding/exposure parameters. An integer and a float is read. The integer decides which algorithm is to be used. The two parameters are passed on to the beddll.dll where they can be used in the sediment transport formulas. The beddll made by Ruther uses the following algorithms:

First integer is 1: Ergiazaroff's method
First integer is 2: Buffington and Montgomery's method
First integer is 3: Vollmers method
First integer is 4: Wu's (2000) method
First integer is 5: Kleinhans' method

Options 2 and 4 is coded in the main SSIIM programs (not the beddll), for both SSIIM 1 and 2.

F 173 SSIIM 1 only. Bed shear stress gradients at inflow/outflow boundary. An integer is read. If 1, the bed shear stress in the boundary cell will not be larger than the neighbour cell in the direction of the

interior domain.

F 174 SSIIM 1 only. Cyclic boundary conditions. Two integers are read. The first integer applies to the water flow computation, and the second to the sediment concentration computation. If the integer is positive, say for example 500, then the inflow boundary values will be set equal to the outflow values for each 500th iteration. If a negative number is given, say -8, then the program will run to convergence, then update the inflow boundary condition and restart the computation. This will be repeated 8 times.

Default *F 174 0 0* (no cyclic boundary condition used)

F 178 SSIIM 2 only. Smoothing algorithms for the free surface, used for the F 36 parameter being 1 or between 11 and 39. An integer is read, which can be between 1 and 4. Each integer corresponds to a different smoothing algorithm.

Default: *F 178 0* (algorithm not used)

F 179 SSIIM 2 only. Upwind function used for the *F 36* parameter being 1 or between 11 and 39. Two integers are read. The algorithm is invoked if the first integer is 1. The second integer will cause a reduction the upwind effect if it is 1.

Default: *F 179 0 0* (algorithm not used)

F 182 SSIIM 2 only. Reduction of critical bed shear stress due to sloping bed. An integer is read. If it is 1, the same algorithm as *F 7 B* is used (Brooks, 1963). If the integer is 2, then the algorithm is only used for cells that have a dry neighbour. If the integer is 3, then the lateral slope in the formula will be the maximum slope. The same formula is used only for the side cells if the integer is 4. If the integer is 5, the empirical formula by Dey (2003) is used. It is only used for the side cells if the integer is 6. The formula by Lane (1955) is used if the integer is 7 or 8. If the integer is 8, the formula will only be applied to the border cells.

Default: *F 182 0*

F 185 SSIIM 1 only. Damping of turbulence close to the water surface. An integer and a float is read. If the integer is 1, a formula similar to the wall laws will be used for the epsilon equation. This will give increased values of epsilon at the water surface and turbulence damping. The float is an empirical coefficient in the damping function. Typical values: 0.0046-0.43.

F 187 SSIIM 2 only. An algorithm to reduce the water level gradients at the borders of the geometry. The algorithm is used in connection with *F 36* 2, 4, 7, 8, 9. An integer is read. If it is 1, the algorithm is used.

Default: *F 187 0*.

F 188 SSIIM 2 only. Integer determining which block is to be computed for sediment transport. Options:

0: All blocks (default)
-1: only nested blocks
n: only block no. n.

Example: *F 188 3* : Only compute sediment transport for block no. 3.

Default: *F 188 0* (all blocks)

F 189 SSIIM 1 only. Large roughness algorithms. Special algorithms designed for situations where the bed roughness is larger than the vertical grid cell size close to the bed. An integer and a float is read. The integer determines which algorithm is used, and the float is a parameter in the algorithm.

Several algorithms and approaches have been tested, but not extensively. Currently, the most promising algorithm seems to be an immersed boundary method with a linear velocity profile: *F 189 5 0.5*, but much more work needs to be done.

F 190 SSIIM 1 only: Algorithm to decide if to use cohesive forces or not for the sediments. An integer is read. If it is zero, the cohesive forces from the *F 131* data set will only be used if the bed level is below the original level. If the bed level is above the original level, the cohesive forces are not used.

F 191 SSIIM 2 only. When connecting blocks in the *GridEditor*, the graphics pointer have to be placed within a certain accuracy. The default is 0.01 mm. For large geometries, this value may be raised to get a successful connection.

F 192 SSIIM 2 only: The parameter decides how many cells are used in the vertical directdion in the nested grid in relation to the coarse grid. The parameter is the ratio of:

number of cells in the vertical direction for the nested grid

to

number of cells in the coarse grid

Default: 1.0

F 194 SSIIM 1 only: Empirical parameter in a formula for adding turbulent eddy-viscosity in areas of vegetation. Default value: 0.0 (no additional turbulence). Values may be in the order of 0.067-0.11.

F 195 SSIIM 1 only: Roughness on side walls. Two floats are read. The first float is the roughness on the side wall where j=2. This is the right wall for the default flow direction. The second float is the roughness on the other side wall.

F 198 Sand slide dll. An integer is read. If it is above zero, the algorithms in the *slide1dll.dll* or *slide2dll.dll* files are used. The two files are made for SSIIM 1 and SSIIM 2 respectively.

F 200 Residual norms for k and ε. An integer and two floats are read. The first float is the residual norm for k and the second is the residual norm for ε. The values are used instead of the average inflow

values if the integer is above zero.

F 201 SSIIM 2 only: Parameters for the *vegdata* file. Three integers are read. The first is the number of variables in the *vegdata* file. The second is the number of vertical elevations. The third is the number of time steps in the file.

This data set has to be present in the *control* file if values for multiple times are to be used in the *vegdata* file.

Default: *F 201 1 4 1*

F 202 SSIIM 2 only. Logarithmic inflow velocity profile. An integer and a float are read. If the integer is above zero, then the inflow sections with have a logarithmic profile in the vertical direction. The float is the roughness value that will be used in generating the logarithmic profiles. Note that all inflow profiles will be logarithmic if this data set is used. If the parameter is not used, a uniform profile is used.

F 206 Maximum number of processors used for the parallel versions of SSIIM. An integer is read, which gives the maximum number of processors. If it is above the number of processors available on the computer, then the maximum available processors are used. The actual number of processors used is written to the *boogie* file.

Default: *F 206 0* (parallellized algorithms not used)

Note this data set will only work on parallel versions of SSIIM.

F 207 SSIIM 1 only. Algebraic stress model DLL. Two integers are read. If the first one is above zero, then the algebraic stress model in the *stress1dll.dll* file will be used instead of the other turbulence models in SSIIM 1. The second integer is the size of the array sent to the DLL from the main program.

F 208 SSIIM 1 only. Order of the discretization of the time-term. An integer is read. If this is 1, then a second-order backwards scheme is used for the time term. Default value: 0, meaning a first-order backward Euler method is used. This data set is usually only used if modelling large eddies (URANS).

F 209 SSIIM 2 only. Scaling depth for grid generation. The default value is the largest depth in the geometry. The value is used for deciding how many grid cells there will be over the depth for a given location in the geometry.

F 211 SSIIM 1 only. Convergence criteria for the water flow computations.

Default: *F 211 0.001*

F 212 Special post-processing print-out. An integer is read. Depending on the value and which SSIIM version, varying extra print-out is given. The print-out is done when the *result* file is written.

1. Works only with SSIIM 1. The average bed velocity vector in the grid direction and normal to the grid direction is printed to the *boogie* file. The grid direction is here defined as parallel to the grid lines in the i-direction, which in the default configuration is in the main flow direction.:

2. Works only with SSIIM 1. Writes the average velocity vector for all grid cells to the *boogie* file. Also writes the average bed shear stress.

3. Works only with SSIIM 1. Writes a file *innflow.t*, which has the same format as the *innflow* file. The values in the file correspond to the last cross-section of the grid. This enables the user to take the values from the last cross-section and give them into the first cross-section.

4. Works only with SSIIM 1. Writes a file *koordina.in*, which has the same size as the *koordina* file, but it is made up of only cross-sections similar to the first cross-section. Together with the 3 option, this enables the user to compute uniform channel values for the upstream profile.

12. Works only with SSIIM 2. Writes a file *cellvol*. This file uses the *geodata* file and the grid to specify how much of the cell volume is located at given levels. 100 values of levels in meters and volume are written to the file. The information can be used to make a capacity curve for the lake/reservoir.

F 218 SSIIM 2 only. Debug information. Two integers are read. When the program has done as many iterations as the first integer, a large number of debug information will be written to the boogie file from the cell which has the same number as the second integer.

F 219 SSIIM 2 only. Parameter to invoke an automatic restart after the program has crashed. The relaxation parameters are lowered before the restart. The integer tells how many times the procedure should be repeated. Maximum 4 times.

F 221 SSIIM 2 only. Convergence stopping of the program. In a steady situation, the program stops when the residuals are below 0.001. In a time-dependent case, the program will not stop if the residuals are below 0.001. However, if time-terms are used to improve convergence of a steady situation, the program should still stop.

An integer is read. If it is 0, the program will not stop in time-dependent computations, when the residual is below 0.001. If the integer is 1, the program will stop.

Default: *F 221 0*

F 222 SSIIM 2 only. Downstream depth algorithm. An integer is read, which can be 0 or 1. If 1, an algorithm is invoked to try to prevent the downstream bed level to rise to heights where it will block the outflow.

Default: *F 222 1* (the algorithm is used by default)

F 224 SSIIM 2 only. One float is read. In a time-dependent water flow computation with a free surface, the free surface will only be updated if the residuals for the Navier-Stokes equations are below 100.0. Using this data set, the value can be changed as the float is used instead of 100.0.

F 225 SSIIM 2 only. Two floats are read, which are used to scale the values in the *geodata* file. The first value is a factor, which is multiplied with all the values. The second value is added to all the values. This can for example be used to model a physical model test if measurements of the prototype exist, or the other way around.

Note that the scaling is done only when reading the values. When editing the *geodata* points in the Grid Editor, and then writing a new *geodata* file, the scaled values are written. Reading the newly

generated *geodata* file back in again and keeping the *F 225* data set, gives a double scaling of the points.

F 233 Algorithm to use a depth-averaged pressure field to compute the water surface elevation changes instead of the pressure in the surface cells. An integer 6 can be used for both SSIIM 1 and SSIIM 2. In SSIIM 2 an integer 7 will use an algorithm similar to 6, but with smaller elevation changes due to the inclination of the surface of the cell.

F 234 SSIIM 2 only. Algorithm to modify the downstream boundary condition when using a free surface algorithm with gravity, for example *F 36 15*. An integer is read. If 1, a hydrostatic pressure is used. If 2, the fluxes at the downstream boundary are set to zero.

F 235 SSIIM 2 only. Algorithms to reduce instabilities in triangular cells. An integer is read, and depending on its value, a number of different algorithms can be chosen. One of the most successful algorithms is 10, giving extra relaxation in the triangular cells. The relaxation factors can be modified on the *F 244* data set.

Default: *F 235 0* (not used)

F 237 SSIIM 2 only. The data set can be used to specify the water discharges instead of using the values in the *unstruc* file. An integer and a floating point number is read. The integer is an index for the discharge group. The floating point is the discharge. Multiple *F 237* data sets can be used for multiple discharge groups.

F 238 SSIIM 2 only. Parameters in the nested grid algorithms. An integer and a float is read. If the integer is 1, the top of the nested grid will get the value of the float. If the integer is 2, the bottom of the nested grid will get the value of the float. If the integer is 3, the water level in the nested grid is interpolated from the coarse grid. If the integer is 4, the pressure in the nested grid so that the water level is on average approximately the same in the nested and the coarse grid. The algorithm is only implemented for *F 64 8, 11* and *13*.

Default: *F 238 0 0.0*

F 239 SSIIM 2 only. Two integers are read, giving the maximum number of iterations in the algorithm for the free surface. The first integer is used for the *F 36 7,8,9* and *10* options. The second integer is used for the *F 36 4* option.

Default: *F 239 50 350*.

F 242 Number of maximum loops in bed change algorithm to distribute bed changes to corners.

Default: *F 242 1000* (SSIIM 1), *F 242 100* (SSIIM 2)

F 243 SSIIM 1 only. Integer to invoke the bgraddll.dll function. It is used to compute the concentration in a bed cell as a function of the max. potential concentration, fluxes, fall velocity, areas, grain size distributions, sediment thickness etc.

F 244 SSIIM 2 only. Two relaxation factors used in the algorithms to reduce instabilities in triangular cells. The first floating point is used for the velocities in the cells, in the *F 235 10* algorithm. The second integer is used for the fluxes on the cell surfaces, if *F 235* is between 8 and 23.

Default: *F 244 0.5 0.8*

F 246 SSIIM 2 only. Algorithms to stabilize the free surface algorithm *F 36 7*. Three integers and a float are read. The algorithm works on the connection between the cell that is to be computed and each of its four or eight neighbors.

If the first integer is 1 and the water is coming into the cell, or the integer is 2, a limiter will be invoked on the water depth in each cell. Different types of limiters can be used, depending on what the third integer is.

If the second integer is 1, the a_p term in the equation is increased if the Froude number is between 0.9 and 1.1. Around supercritical flow the above a_p term sometimes can be close to zero, causing a crash. If the second integer is 2, the a_p term will never be below 1.0. If the second integer is 3, the ap term will be increased if the Froude number is between 0.5 and 1.5.

The third integer decides the magnitude and conditions of the depth limiter invoked by the first integer. If the integer is above zero, the limiting value is decided by a formula in the *sfdifdll.dll* file, which can be coded by the user. Negative values indicate different alternative hard-coded formulas, not in the DLL. The following options for the limiter are:

-1: the depth if the Froude number is above 1
-2: the depth * 1.1 if the Froude number is above 1
-3: the depth * the Froude number if the Froude number is above 1
-4: the depth if the Froude number is above 0.9
-5: same as option -3, except the Froude number is taken as the maximum of the cell and its neigbors
-6: the depth if the Froude number is above 0.5

The float is a limiter on the allowable surface slope used in the determination of the a_{nb} coefficients for the *F 36 7* algorithm.

Default: *F 246 1 1 0 0.1*

F 249 SSIIM 2 only. An integer is read. If 1, then negative sediment thicknesses are allowed. The feature is used to present measured bed elevation changes.

F 251 SSIIM 2 only. Different Shields curves. An integer is read. If non-zero, a lower or higher Shields curve will be used.

F 252 SSIIM 2 only. A relaxation factor for the outflow discharge, if a zero-gradient (update) boundary condition is used.

Default: *F 252 0.9*

F 256 SSIIM 2 only. Maximum sediment concentration at the bed. Default 0.1

F 260 Flocculation DLL. An integer is read. If it is above zero, the *flocdll.dll file* will be used to compute flocculation of the sediments. Note that this will only work if the *F 37 2* option is used.

F 261 SSIIM 2 only. Nested grid algorithm. An integer and a float is read. If the integer is 1, the nested domain will be coupled with the coarse grid when computing water flow. If the integer is 2, the coupling will also be applied for the sediment concentrations. The float is a relaxation coefficient for the interpolation. Its value is between 0 and 1.

F 264 SSIIM 2 only. Variable bed sediment density algorithms. An integer is read. If it is above 0, then it will be used by the functions in the *vdmldll.dll* file, computing variations in the bed sediment density. If it is -1, then a hard-coded algorithm is used.

Default *F 264 0*

Note that these algorithms will only be used if the *F 37* data set is set to 3 (multiple bed layers).

F 267 SSIIM 2 only. Faster display of map graphics. An integer is read. If it is 1, then quadrilaterals will be used instead of contours in displaying the Map graphics. This may give faster graphics for large grids.

Default: *F 267 0*.

F 268 SSIIM 2 only. Decision about the nested blocks being printed to the Result/Tecplot/Paraview files. An integer is read. If it is 0 (default), all the blocks are printed. If 1, then only the coarse grid is printed. If the integer is 2, then only the nested blocks are printed.

F 272 SSIIM 2 only. Alternative algorithm to compute the production of turbulent kinetic energy, P_k, as proposed by Kato and Launder (1993). This is invoked if the integer read on the data set is 1.

Default: *F 272 0*.

F 274 SSIIM 2 only. Bed angle parameters. An integer is read. If it is larger than zero then the program will try to read the *bedangle* file.

Default: *F 274 0*

F 275 SSIIM 2 only. Modifications of the epsilon constants. Two floating point numbers are read, which gives two of the epsilon constants in the k-epsilon model.

Default: *F 275 1.44 1.92*

F 277 SSIIM 2 only. Option to display a graphic view of the sediment continuity defects. This is done if an integer above zero is read. Then the continuity defect is seen when choosing Debug information in the graphics.

Default: *F 277 0*

F 278 SSIIM 2 only. Variations of the *F 36 7* algorithm. The integer 16 uses the same formula as described by Olsen (2015).

Default: *F 278 0*

F 279 SSIIM 2 only. Variations in computing the bed shear stress. Can not be used with the *beddll.* An integer is read. The following options are:

1: The shear stress is computed from the maximum kinetic energy in the bed cell and in the cell above the bed cell.
2: The bed shear stress is computed from the maximum of the shear in the bed cell and the neighbour cells, if the cell corners have been moved inwards (*F 102 1*)

Default: *F 279 0*: Normal bed shear computation from the kinetic energy in the bed cell.

F 281 SSIIM 2 only. Increase in the vertical eddy-viscosity due to dunes. An integer and a float are read. If the integer is read, the vertical eddy-viscosity is increased by adding a value proportional to the float and the bed form height.

Default: *F 281 0* (algorithm not used):

F 283 SSIIM 2 only. Extra damping in the changes of the water surface elevations for the *F 36 7* algorithm, if the Froude number is above 1. An integer is read. If it is 1, then the algorithm is used.

Default: *F 283 0* (algorithm not used)

F 285 SSIIM 2 only. Parameters for the choice of function in the *beddll*. Two integers are read. If the first integer is 1, the function *computeBedConcentration1* will be called instead of *computeBedConcentration*, which is default (integer is 0). The two *beddll* functions have different parameters. The second integer does the same for the *beddll* functions *computeBedSlopeCorrection* and *computeBedSlopeCorrection1*.

Default: *F 285 0 0*

F 286 SSIIM 1 only. The parameter c_μ in the k-ε turbulence model is given.

Default: *F 286 0.09*

F 287 SSIIM 2 only. Algorithm that tries to estimate the outflow water flux from a reservoir, given the inflow and the changes in the water surface elevation of the reservoir. An integer is read. The algorithm is invoked if the integer is 2. The computed outflow flux will override the specified outflow in the *timei* file. If the integer is 3, the computed outflow flux will be checked against the value specified in the *timei* file, and not be allowed to go below this.
If the integer is 5, the outflow will then be limited to be between 0.5 and 2.0 times the discharge in the timei file. If the integer is 6, the same limitation procedure will be used, but then two floats are read after the integer. These two floats will then be used instead of 0.5 and 2.0.

Default: *F 287 0* (algorithm not used)

F 292 SSIIM 2 only. Inner time step. An integer and a float is read. If the integer is 1, the float is used in an inner time step. This means the time step is used for each inner iteration. The purpose is to prevent instabilities, and the method seem to be more effective then most of the earlier methods. This especially applies to velocity instabilities in triangular cells.

Default: *F 292 0 0.0* (algorithm not used)

F 293 SSIIM 2 only. A file where residuals are written for each iteration. The file is called *sigurd*. It makes it easier to make graphics of the residuals in a spreadsheet.

F 294 SSIIM 2 only. An integer is read, giving the number of time steps in the time-dependent *inspace* file.

F 295 SSIIM 2 only. A float is read the float is multiplied with the average vertical distance between the geodata points an the bed level, to produce the roughness values.

Default: *F 295 1.0*

F 297 SSIIM 2 only. An integer is read, indicating which version of the unstruc file is to be written. Default after 11. June 2012: 3. Default before 11. June 2012: 2. The difference between version 2 and 3 is that version 3 contains geometry information also for dry areas, making it possible to start a computation with a dried up area without using a *koordina/koosurf* file. Version 3 also contains more accurate information for the different blocks, making it possible to increase the *G 1* data set parameters and still use the same *unstruc* file. These two features were not possible in version 2.

There is also a version 4 of the unstruc file, which only contains the 2D grid and not the 3D grid. This will be much smaller than version 3, but may produce different number of 3D cells on different computers.

F 300 SSIIM 1 only. Two integers are read, which are used in the sediment concentration solver. The first integer is the number of iterations. The second integer determines if block-corrections is to be used. If the integer is 1, block-correction is used.

Default: *F 300 1 1*

F 301 SSIIM 2 only. A float is read. It is the maximum residual defining a crash of the program.

Default *F 301 1.0e10*.

F 302 SSIIM 1 only. An integer is read. If it is 1, the program will not do the test if the values in the koomin file are higher than the bed level.

Default: *F 302 0*

F 305 SSIIM 2 only. Alternative function for the wall laws. An integer is read. If it is 1, the alternative function is used. This is only implemented for *F 15 0, 8* and *15*.

F 306 SSIIM 2 only. Use of the grain size distribution in the *bedres* file. An integer is read. If it is 1, the sediment grain size distribution in the *bedres* file will be used instead of the *fracres* or the *N* data sets when starting a new computation.

Default *F 306 0*

F 308 SSIIM 2 only. MPI option. An integer is read. If it is above 0, MPI algorithms will be used. Not tested in much detail.

F 310 SSIIM 2 only. Algorithms to adjust the sediment thickness. The sediment thickness can be given in two ways: The *koomin* file in combination with the *unstruc/koordina* file. And the *fracres/bedres* files. The algorithms deal with the situation where the sediment thickness is not the same in the two approaches. An integer is read. If 1, the *koomin* values are used. If the integer is 2, the *fracres/bedres* values are used.

Default: *F 310 0* (this may give wrong answers if the user has not specified the input data correctly)

F 314 SSIIM 2 only. Automatic setting of inflow/outflow areas. Two integers are read. If the first integer is 1, then the inflow area in *Discharge Group 1* will cover the whole upstream cross-section of the first block and be an inflow area. If the second integer is 1, then the whole downstream cross-section of the first block will be defined in *Discharge Group 2* to be outflow. The data set can be used instead of using the *Discharge Editor*.

F 322 SSIIM 2 only. Shallow Water Equation parameters. Two integers are read. If the first one is 1, the time step source terms will be included in the solution. If the second is 1, the convective term in the Shallow Water Equation are included in the solution. Note that this is only for the computation of the free surface, with *F 36 9* and *F 321 1*.

Default: *F 322 0 0*

F 323 SSIIM 2 only. New free surface function. An integer is read, and the new function is used instead of the old one of the integer is 1. The new surface function includes the Shallow Water equation option, *F 36 9*.

Default: *F 323 0*

F 328 SSIIM 2 only. New function for the water flow computation. An integer is read. If it is 1, the new function is used.

F 329 SSIIM 2 only. Print-out options. A series of up to 19 integers are read. Each integer specifies a file that can be printed out each time the *P 10* iteration is reached. The following list gives the options:

1st *result* file
2nd *bedres* file
3rd Tecplot 2D

4th Tecplot 2D - nested version
5th Tecplot 3D
6th ParaView 3D
7th ParaView 2D
8th ParaView 2D written to multiple blocks
9th *NagelPtk* file
10th *beddata.sim*: x,y and z values of bed cells
11th a paramerter is read which tells what type of *interres* file is written: the number is the same as on the F 48 data set.
12th *Halvor* file: 2D depth-averaged boundary of the geometry
13th *habitat* file
14th *boogie.spe* file with bed area fraction that has slope over 0.2967 radians.
15th *boogie.spe* file with special print-out, depending on which integer is written:
2: x, water level, slide level, groundwater level
16th *fracres* file

Default: *F 329 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0* (only *result* and *bedres* files are written)

It is not necessary to give in all the zero numbers. For example, if only the Tecplot 2D file is to be written, the following data set can be used:

F 329 0 0 1

F 335 SSIIM 2 only. An ending time for the computations. A float is read, which is the time in seconds when a transient sediment computation stops.

F 337 SSIIM 2 version with MPI only. Discharges for the MPI computation. Two integers and one float is read. The first integer is the block number. The second integer is the discharge group number. The float is the actual discharge, in m^3/s.

F 342 SSIIM 2 only. Vector display interval. An integer is read. If it is 2, only every second velocity vector is shown in the Map graphics. If it is 10, only every 10th vector is shown. Since SSIIM 2 uses an unstructured grid, the vectors may show up in a random pattern in Map graphics. However, if the number of cells in the vertical direction is the same in an area, the vectors may form a pattern, depending on the value on the data set.

F 343 SSIIM 2 only. Convergence improvement algorithm for the free surface computation. An integer is read. If it is 2, then a block-correction algorithm is used along the main axis of the grid. If the integer is 3 then a classical multi-grid method is used.

Note that the convergence acceleration algorithms may give poorer stability for large time steps.

F 345 SSIIM 2 only. Convergence criteria for the Casulli free surface algorithm. Default 10^{-5}.

F 350 SSIIM 2 only. Variable time step parameters. Four floats are read. The first float is the maximum time step. The second fload is the minimum time step. The third float is a reference discharge, Q_{ref}, and the fourth float is the parameter, n. The two last parameters are used in the formula for the variable time step, which is given by Olsen and Hillebrand (2018), Eq. 5.

F 355 SSIIM 2 only. An integer is read which chooses which algorithm is used to compute pressure gradients for computations with free surface and gravity.

F 364 SSIIM 2 only. Two floats are read. These are the minimum and maximum values used to scale the colors for the *geodata* points in the *GridEditor*.

F 365 SSIIM 2 only. An integer is read. If it is 1, then the points in the *interpol* file will be shown in the *Map* graphics.

F 366 SSIIM 2 only. An integer is read. If it is 1, the momentum of the upstream inflowing water is set to zero.

F 369 SSIIM 2 only. An integer is read. If it is 1, then some algorithms will be invoked to check for some type of bugs in the program. If bugs are found, information is written to the *boogie* file.

F 371 SSIIM 2 only. An integer is read. If it is 62, then an algorithm will be used to avoid grid splitting. Grid splitting may occur if the wetting/drying algorithm divides the grid in more than one part, and the inflow/outflow regions are no longer connected.

F 378 SSIIM 2 only. An integer is read. If it is 1, a file called *thalweg* will be written. This contains the x and y coordinates of the deepest point in each cross-section of the grid.

F 379 SSIIM 2 only. Lowering of water level in cells with very low bed shear stress, so that these are removed from the grid. An integer and two floats are read. The algorithm is used if the integer is 1. The second integer is multiplied with the first integer on the *F 94* data set. The algorithm will only be used if the water depth is below this number. The second float is the critical bed shear stress for invoking the algorithm.

F 385 SSIIM 2 only. Cohesion parameters. An integer and a float is read. Sediment cohesion is used if the integer is 1. The float is the cohesion in Pascal.

F 386 SSIIM 2 only. Dreding algorithm. An integer is read. If it is 1, the dredging algorithm is invoked. Then, the *bagger* file has to be used.

F 387 SSIIM 2 only. Minimum depth in the grid (meters). This is used to reduce stability problems caused by too small water depths.

F 388 SSIIM 2 only. Relaxation coefficient for the velocities in the default SIMPLE correction algorithm.

F 389 SSIIM 2 only. Integer saying how many iterations are computed between writing *alldata* files.

F 392 SSIIM 2 only. An integer is read. If it is 1, then the bed changes in the *alldata* file will be set to zero when reading the *alldata* file. This means the bed changes shown by SSIIM 2 will only be values computed **after** the *alldata* file is read.

F 393 SSIIM 2 only. An integer is read. If it is 1, then the limit of the movable bed will be set equal to the original bed level read from the *alldata* file.

F 394 SSIIM 2 only. Removes ponds in the grid, made up of more than one cell. A pond is a wetted area that is not connected with the inflow/outflow region. An integer is read *F 394 10* activates the algorithm.

F 396 SSIIM 2 only. Flag that affects the bed level changes at the grid boundary. If it is 1, less changes will occur at the boundary. Default 0.

F 398 SSIIM 2 only. Coefficient in vanRijns formula for roughness as a function of d_{90}. Default 3.0.

F 399 SSIIM 2 only. An integer is read. If it is 1, the program will not stop if the x or y coordinates in the koomin file is not the same as in the grid.

F 405 SSIIM 2 only. An integer is read. If it is 1, a time step is added in the equation for the free water surface location, *F 36 7*.

F 406 SSIIM 2 only. A float is read. This is added to the a_{nb} coefficient in the free surface algorithm invoked by the *F 36 7* data set.

5.3.2 The *G* data sets

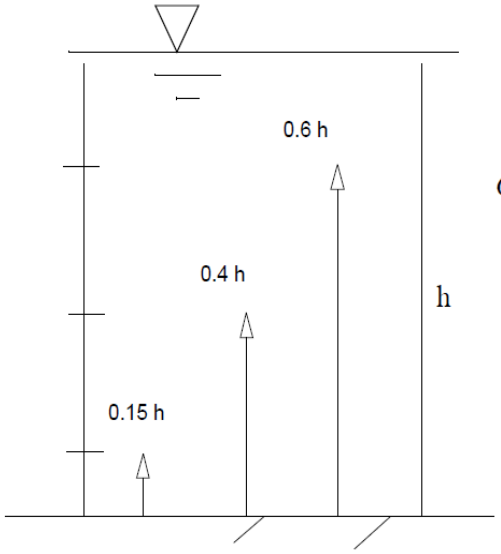
G 1 Four integers are read, called *xnumber*, *ynumber*, *znumber* and *lnumber*.

For SSIIM 1, this gives the number of cross-sections, grid lines in the streamwise direction, and vertical direction, respectively, for a structured grid. The last integer is the number of sediment sizes. This data set must be present in the *control* file. The program will read these values and allocate space for the arrays accordingly at startup.

For SSIIM 2, the unstructured grid will also use structured arrays for connecting the different blocks. The blocks will be put beside each other in the lateral direction of the grid. The default grid size is 300x300 cells. If the grid size is smaller, it may be an advantage of using smaller numbers on this data set, to reduce the memory requirement. If the length of one block (number of cross-sections) is larger than 300, this data set must be changed accordingly. If the number of blocks times its widths is larger than 300, this data set must also be changed accordingly. The third integer is the maximum number of grid lines in the vertical direction. The last integer is the number of sediment sizes.

G 3 **For SSIIM 1**: Vertical distribution of grid cells. This is further explained in the figure below, where an example is given. This data set must be present in the file.

The values are given as a percentage of the depth only with the grid options *F 64 2* and *F 64 5*. For *F 64 0* and *F 64 1*, the values are level in meters, and the longitudinal and lateral grid lines are completely horizontal.



G 3 0.0 15.0 40.0 60.0 100.0

For SSIIM 2: The same distribution as described for SSIIM 1 is used if *F 64 2* and *F 64 5* is used in the *control* file. For *F 64 0* (default) and *F 64 1*, the values on the *G 3* data set are level in meters, and the longitudinal and lateral grid lines are completely horizontal.

G 5 **SSIIM 1 only**. Sediment sources. Six integers and a number of floats are read. The number of floats is the same as the number of sediment sizes. The integers indicate a region of the grid. The first two are in the streamwise direction, the following two are in the cross-stream direction and the two last integers indicate the vertical direction. The following floats gives the sediment concentration in volume fractions. Only one *G 5* data set can be used.

Example: Sediment concentration 0.001 flows into the top of the geometry in an area given by the following cells: j=2 to j=4 and i=3 to i=5. It is assumed that there are 11 grid lines in the vertical direction. This gives the following data set:

G 5 3 5 2 4 11 11 0.001

Note that a volume concentration of 0.001 with a specific sediment density of 2.65 is equivalent to a concentration of 0.001 x 2.65 x 1 000 000 = 2650 ppm

G 6 Data set for calculating water surface elevation with an adaptive grid. Three integers and two floats are read:

iSurf
jSurf
kSurf
RelaxSurface
ConvSurface

The *RelaxSurface* variable is a float relaxing the estimation of the increment to the new recalculated water surface. Use low values if you experience instabilities.

The *ConvSurface* variable is a float setting the limit for when the water surface should be recalculated. The water surface will be updated when the maximum residual of the equations are below this parameter. Recommended value: 0.01 - 1.0

The first three integers are interpreted differently in SSIIM 1 and SSIIM 2.

SSIIM 1:

Note: The *G 6* data set is not used if *F 36 1* is used in the *control* file.

The three integers *iSurf, jSurf, kSurf* indicate a cell in the grid. The water surface in this cell is not moved. In the present implementation, *kSurf* have to be equal to znumber + 1. This means the cell has to be on the water surface. If not, a warning message is sent to the *boogie* file, and *kSurf* is set to *znumber + 1*. The computations continue afterwards.

Example: *G 6 31 7 9 0.1 0.1*

Seen from above, the water elevation in cell (31,7) will not move during the computation of the free surface.

SSIIM 2:

In SSIIM 2 the grid is unstructured, so it is only necessary with one index to reference a cell. The first index, iSurf, is then used to point to this cell. The water level above this cell will not be moved during the computations. Normally, the other two variables, *jSurf* and *kSurf* should be set to zero. However, it is also possible to use two reference cells that do not move. This is not correct from a hydraulic point of view, but it can be done to improve stability. The number of the second cell is then given as the second integer, *jSurf*. The third integer, *kSurf*, is normally zero. However, if the water level is changed at only one location, for example the downstream boundary, the *kSurf* integer can be set equal to the number of the discharge group at the outlet, given in the *DischargeEditor*. This will then cause the water level over the whole outlet cross-section to be lowered simultaneously and in a horizontal line, instead of being lowered at one point.

Selecting the surface index is usually done in the map graphics, where the cell indexes are seen. Note that a dynamically changing grid must not be computed during this procedure, and the *F 112* data set must not be used in the *control* file when finding the number. The *F 112* data set can be re-inserted into the *control* file after the *G 6* numbers are found.

When the grid cell indexes change for a dynamic grid, the location of the cells in the initial grid is used.

Example: *G 6 35310 43673 0 0.1 0.1*

The water surface above cells 35310 and 43673 is fixed during the movement of the water surface.

For SSIIM 2, also see the *G 62* data set.

G 7 **SSIIM 1 only**. This data set specifies water inflow on geometry sides, bed or top. Each inflow/outflow location is given on one *G 7* dataset. It is possible to have up to 19 *G 7* datasets. When

the *G 7* data sets are used, the default inflow/outflow discharges are not used. Therefore, it is then necessary to use at least two *G 7* data sets if they are used.

On each dataset, eight integers and four floats are read. The names of the variables are:

G 7 type side a1 a2 b1 b2 parallel update discharge Xdir Ydir Zdir

Each variable is explained in the following:

type: 1: outflow, 0: inflow.

side: 1: upstream inflow cross-section when not using G 7 data sets
-1: downstream outflow cross-section when not using G 7 data sets
2: along the right bank when not using G 7 data sets
-2: along the left bank when not using G 7 data sets
3: discharge through the channel bed
-3: discharge through the water surface boundary

a1,a2,b1,b2: four integers that determine the limits of the surface, by the indexes of the cells. This is further described in the figure below.

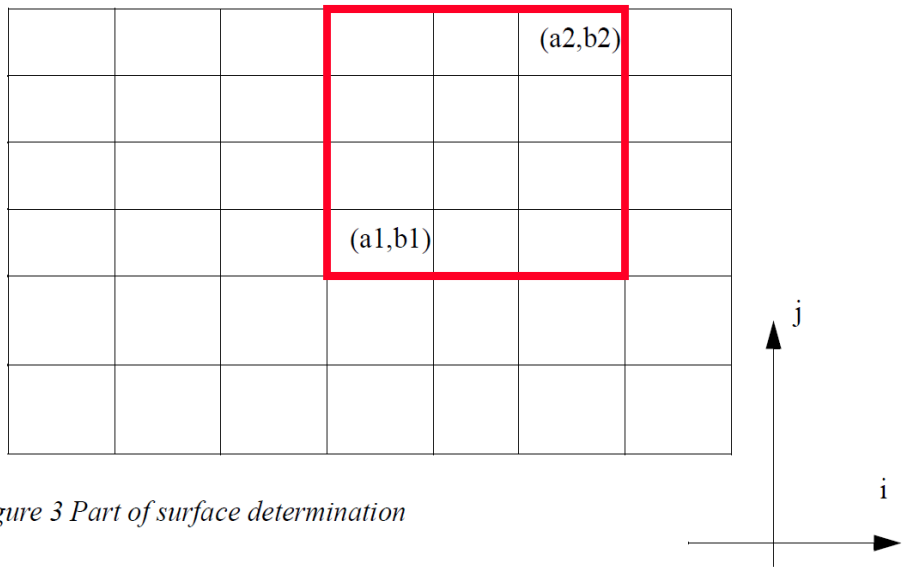


Figure 3 Part of surface determination

parallel: direction of the flow:
0: normal to surface
1: parallel to grid lines normal to surface
2: direction is specified (vector directions)

update: 0 for not update, 1 for update.
(only partly implemented)

discharge: water discharge in m^3/s. Note that the sign of the discharge must correspond with the direction of the desired flow velocity. Positive discharges indicate velocities in direction of increasing grid line numbers.

Xdir: direction vector in x-direction
Ydir: direction vector in y-direction
Zdir: direction vector in z-direction

Example: *G 7 0 1 2 11 2 11 0 0 32.0 1.0 0.0 0.0*

This example specifies inflow in the most upstream cross-section. The inflow area is from cell no. 2 to cell no. 11 in both lateral and vertical direction. The flow direction is normal to the cross-section. The discharge is 32 m^3/s

Remember to define the walls of the boundary when this data set is used. The walls with no inflow must be closed with the *W 4* data set. If inflow through a side set as wall is specified with the *G 7* data set, the wall laws must be removed using the *W 4* data set. The default walls are on the sides of the channel. The first and last cross-sections have the inflow and outflow by default.

Also note that it is not possible to have inflow through the free water surface. If such a case is to be simulated, it is necessary to model a closed conduit (*K 2 0 0*, + addition to *koordina* file), and then to open a hole in the roof.

If the *G 7* data sets are not coded correctly, there will be a continuity error. It is then advisable to look at the velocity vectors in the SSIIM graphics to see if the vectors computed in the first iterations gives a picture that looks reasonable. Remember the red lines shows solid walls and blue lines show inflow/outflow. The vectors close to inflow/outflow regions should point roughly in the right direction after the first iteration.

For SSIIM 2, the data set is not used. Instead, the inflow/outflow is specified in the *Discharge Editor*. The information is stored in the *unstruc* file.

G 8 **SSIIM 1 only**. Values for initial velocities. Up to 19 *G 8* data sets can be used. Six integers are read first to specify the volume that is being set. Then three floats are read, which gives the velocities in the three directions.

G 8 i1 i2 j1 j2 k1 k2 U V W

G 11 **SSIIM 1 only**. Source terms for the velocity equations. Six integers and two floats.

i1 i2 j1 j2 k1 k2 source relax

The first six integers are indexes for the cells that are influenced by the source term. The source variable is the form factor times a diameter of a cylinder in the cell times how many stems there are in one cell. The relaxation variable is recommended set between 1.0 and 2.0

G 13 Outblocking option that is used when a region of the geometry is blocked out by a solid object. An integer is read first, which determines which sides the wall laws will be applied on. The following options are possible:

0: No wall laws are specified
1: Wall laws are used on the sides of the block
2: Wall laws are used on the sides and the top of the block
3: Wall laws are used on the sides, the top and the bottom of the block

Six integers are then read: *i1 i2 j1 j2 k1 k2*. These integers define the cells of the block. The two first integers are the first and the last cell in the *i*-direction. The next two integers are the first and the last cell in the *j*-direction. The last two integers are the first and the last cell in the vertical direction.

When making blocks, note that there must be at least two free cells (not blocked out) between each block or to the wall. It is recommended to use more free cells than two, to resolve the flow pattern between the blocks.

Up to 49 *G 13* data sets can be used.

For SSIIM 2, the first and the two last integers are not used, but numbers must be given in anyway. The data set will then only have an effect when given to the *control* file before the grid is generated.

G 14 SSIIM 1 only. Debug dump option, where a variable in a cell is written to the boogie file. Four integers are read. The first integer indicate which equation. Velocities in *x, y* and *z* directions are denoted 1,2 and 3, respectively. 5 and 6 are used for k and ε, respectively.

The next three integers are cell indexes *i, j* and *k*.

Example: *G 14 1 3 4 6* causes velocity in x-direction for cell i=3, j=4 and k=6 to be written to the boogie file for each iteration.

Up to 29 *G 14* data sets can be used.

G 16 SSIIM 1 only. Local vertical distribution of grid cells. This data set can be used when a different distribution of grid cells than what is given on the *G 3* data set is wanted in some parts of the geometry. Four integers are read first. These tells which area are affected by the changed distribution. Then znumber floats are read, similarly to what is on the *G 3* data set.

Example: *G 16 2 3 1 4 0.0 50.0 75.0 100.0* when *znumber* is 4, gives the new distribution for the eight vertical lines *i*=2 to *i*=3 and *j*=1 to *j*=4.

Up to 500 *G 16* data sets can be used.

G 18 SSIIM 1 only. Boundary inflow specification for water quality calculation. Six integers are read first, specifying the location of the inflow. Then another integer is read, specifying the variable. The integer correspond to the value on the *Q* data set. Then a float is read, which is the value of the variable. The last two numbers are floats, which gives the starting and ending time for the variable to flow into the geometry (in seconds).

Example: *G 18 1 1 2 4 2 5 0 0.01 100.0 200.0*

This gives an inflow at the upstream boundary (*i*=1) in cell *j*=2 to 4 (lateral) and *k*=2 to 5

(vertical). This is variable no. 0, and a value of 0.01 is specified after calculated time 100.0 seconds. The inflow ends after 200.0 seconds

Up to 100 *G 18* data sets can be used.

G 19 SSIIM 1 only. OpenGL 3D surfaces parameters. One surface is described on each *G 19* data set. Up to 50 *G 19* data sets can be used.

Each data set consist of eight integers. The first integer specifies the number of the grid line. The second integer is an index showing the main direction of the grid surface. The following options are possible:

1: cross-section
2: longitudinal profile
3: plan view

The following four integer defines the corners of the surface. The last two integers are presently not used for anything, but they must be given.

Example: *G 19 11 3 2 5 2 6 0 0*

This gives a surface along the grid surface *k*=11, from *i*=2 to 5, and *j*=2 to 6.

If no *G 19* data sets are given, a default data set is used this is:

G 19 1 3 2 xnumber 2 ynumber 0 0

This will give the bed of the geometry. The parameters *xnumber* and *ynumber* are given on the *G 1* data set, and are the number of cross-sections and lines in the streamwise direction, respectively.

G 20 SSIIM 1 only. Sediment sources. This data set is used for inserting sediment into other areas than what is defined on the *I* data set.

The data consist of seven integers and a float. The first six integers define a surface, by giving indexes for streamwise, lateral and vertical direction. The seventh integer is an index for the sediment size. The float is last, and it is the sediment concentration.

Example I: *G 20 2 10 1 1 2 7 1 0.001*

A concentration of 0.001 (by volume) is given for size 1. The concentration is given on the right side wall of the volume (*j*=1 to 1, repeated indexes). The surface area is within the indexes *i*=2 to 10 and k=2 to 7.

Example II: *G 20 2 10 2 4 12 12 3 0.002*

A concentration of 0.001 (by volume) is given for size 3. The concentration is given on the water surface, as there are 11 cells in the vertical direction. The surface area is within the indexes *i*=2 to 10 and *j*=2 to 4.

Up to 50 *G 20* data sets can be used.

G 21 SSIIM 1 only. This data set is used for determining fluxes through special parts of the geometry. As a default, the boogie file will only give the fluxes through the four sides of the geometry. Additional surfaces can be specified on this dataset.

Six integers are read. The first integer specifies if the surface is a cross-section (1), a longitudinal section (2) or a horizontal section (3). The second number specifies the section number. The following four integers specifies the surface area.

Example:

G 21 1 83 2 9 2 21
G 21 1 83 2 9 2 6

The two data sets specifies two cross-sectional surfaces, located at node *i*=83. Both surfaces covers *j*=2 to j=9, but the first surface is from *k*=2 to k=21, while the second surface is from *k*=2 to *k*=6.

The effect of the data sets is that an extra line is written to the *boogie* file for each data set. The example above gives the following print-out in the boogie file. The bold text is specific for the G 21 data sets.

Trap efficiency after 49 iter: all values in kg/s
l=1: Trapped: 0.0510563, Fluxes (I1,I2,J1,J2): 1, 0.948, 0, 0 Resid: 0.0008
Flux 1 = 0.948952
Flux 2 = 0.881389

The numbering of the surfaces follows the grid lines, which is different from the numbering of the cells. If the water is flowing in a direction of decreasing grid cell numbers, then the sediment flux will be equal to the concentration in a cell multiplied with the water flux in the cell side with the cell number minus one. To take this into account, the user can specify a negative sign for the integer indicating the direction. For example -1 instead of 1 for a cross-section where the water is flowing into the geometry at the last cross-section, or out of the geometry at the first cross-section.

Up to 20 *G 21* data sets can be used.

G 22 SSIIM 2 only. Data set to model horizontal constructions, for example bridges. Four integers and three floats are read. The first four integers, *i1,i2,j1,j2* are indexes describing an area of cells in the 2D depth-averaged grid. This is where the construction is to be placed. The first float is the lowest elevation of the structure. The second float is the highest elevation of the structure. The third float is a velocity reduction coefficient. For solid objects, it can have a value of 1.0 or more. Higher values will give more reduction and lower velocity. For porous objects, the value can be lower than 1.0. If the value is lower than 0.7, then the velocity reduction formula is changed into a porous drag formula, where the velocity reduction coefficient is the solid volume fraction of the object.

The program automatically finds which of the vertical cells are within the area of the construction. This is useful when the grid moves vertically.

Up to 19 *G 22* data sets can be used.

G 23 SSIIM 1 only. Data set to model scour around submerged structures. If this data set is not used,

the position of the grid intersection will move vertically as the grid changes. This data set fixes one grid surface. Five integers are read. The first two are indexes for the first and last cross-section of the surface. The next two are the first and last index of the grid line numbers in the lateral direction. The last and fifth integer is an index for the vertical level.

Example: *G 23 31 45 1 18 6*

Surface number 6 from the bed is fixed in the region between cross-sections no. 31 and 45 and between the right bank and grid line j=18.

Up to 500 *G 23* data sets can be used, if there are multiple submerged structures.

The data set is mostly used in combination with blocking out a region of the flow. This is done by using the *G 13* data set.

G 24 Data set to determine which variables are written to the ParaView/Tecplot files. First, an integer is read giving the number of variables on the data set. Then, for each variable, a character and two integers are read. The character indicates the name of the variable, as detailed in Chapter 5.19. The first integer gives the level above the bed. The second integer gives the sediment size. For some variables, this information is not relevant. Integers still have to be given, but they are then not used.

Example: *G 24 3 u 1 0 p 2 0 c 1 2*

G 40 Initial vertical distribution of temperature. An integer, n, is read, which gives the number of points in the profile. Then n pairs of floats are read, the first float being a vertical level in meters, and the second float is the corresponding temperature in degrees Centigrade.

Example: *G 40 2 101.0 20.0 88.0 17.0*

At the start of the calculation, the temperature is 20 degrees Centigrade at level 101.0 meters and 17 degrees at level 88.0. There is linear variation between the given levels.

The highest levels must be first in the data set.

G 41 Initial vertical distribution of a water quality parameter. Two integers are first read, where the first integer is the number of the water quality parameter. This corresponds to the Q data sets. The second integer is the number of data points, n, in the vertical direction. Then n pairs of floats are read, the first float being a vertical level in meters, and the second float is the corresponding temperature in degrees Centigrade.

Example: *G 41 4 2 101.0 20.0 88.0 17.0*

At the start of the calculation, the water quality parameter no. 4 is 20 at level 101 meters and 17 level 88.0. There is linear variation between the given levels.

The highest levels must be first in the data set.

G 42 SSIIM 2 only. Multiple vertical surfaces for the OpenGL graphics. A surface is give on each G 42 data set, and up t 20 *G 42* data sets can be given. For each data set, two integers are read. The first integer is a grid node number. This indicates the starting point of the surface. The second integer is a flag indicating the direction of the surface. A zero is in one direction, and 1 is the other. It is necessary

with a trial and error run to get the second parameter right.

G 50 OpenMP parallelization parameters. Ten integers are read. Each integer can be 0 or 1. The algorithms in SSIIM has two versions: One parallel and one non-parallel. If F 206 is above zero, the parallel versions are used. With the G 50 data set, the user can force a combination of serial and parallel algorithms.

Default: *G 50 0 0 0 0 0 0 0 0 0 0*

If one of the integers on the *G 50* data set is 1, then the serial algorithm will be used for this part, even though *F 206* > 0 is used and parallel versions of all the other algorithms are used.

The purpose of the data set is debugging. If the parallel version and the serial version do not give the same result, the *G 50* data set can be used to see which algorithms cause the problem.

The different algorithms used are for SSIIM 2:

1st: coefficient generation for the Navier-Stokes equation, the Power-law scheme
2nd: computation of eddy-viscosity, setting anb coefficients to zero, computing the water flux and making the coefficients for the second-order upwind scheme
3rd: wall laws and source term for the pressure equation
4th: water fluxes computation for the pressure-correction equation
5th: SIMPLE corrections
6th: turbulence computations, wall laws and coefficient generation for k
7th: turbulence computations, wall laws and coefficient generation for epsilon
8th: computation of residuals
9th: solver
10th: time step and residual for k

G 62 **SSIIM 2 only**. Data set for calculating water surface elevation with an adaptive grid. Four integers and two floats are read:

iSurf
jSurf
kSurf
kSurf2
RelaxSurface
ConvSurface

The data set is identical with the *G 6* data set, except that four integers are read instead of three. The fourth integer, *kSurf2*, is the number of the discharge group that has the cell number in the second integer, *jSurf*.

If *jSurf2* is non-zero, the water level over the whole cross-section of the discharge group is changed simultaneously and in a horizontal line, instead of being lowered at one point.

5.3.3 The *I* data set

SSIIM 1 only. Inflow of sediments at the upstream cross-section. An integer is read first, giving

the number of the size fraction. Then the sediment inflow in kg/s is given.

Example: *I 1 3.2*
I 2 4.8

There is 3.2 kg/s sediment inflow of size 1 and 4.8 kg/s of size 2.

Note that this data set only applies for the upstream cross-section. If sediments flow into another surface, the *G 20* data set can be used.

5.3.4 The *K* data sets

K 1 Number of iterations for flow procedure and number that determines the minimum iterations between updates of water surface. Two integers.

Default: *K 1 40000 50000*

K 2 Two integers that indicate if laws of the wall are being used for the water flow computation. If 0, wall laws are used, and if 1, zero-gradients are used. The first integer applies to the side walls. The second integer applies for the surface. Wall laws are always used for the bed, if not changed by the *W 4* data set. Default: *K 2 0 1*.

K 3 Relaxation factors. Six floats. For the three velocity equations, the pressure correction equation and the k and ε equation. For further description of the relaxation factors, see Chapter 3.

Default: *K 3 0.8 0.8 0.8 0.2 0.5 0.5*

K 4 Number of iteration for each equation. Six integers. Default: *K 4 1 1 1 5 1 1*

K 5 Block-correction. Six integers are read, one for each of the six water flow equations. If the integer is 1, block-correction is used. For the TSC algorithm in SSIIM 2 for Windows, the integer 2 indicates that the block-correction is only used in the first of the inner iterations in each time step. For SSIIM 2, the integer 10 used in connection with *F 168* will invoke a multi-grid algorithm.

Default: *K 5 0 0 0 0 0 0*

K 6 Six integers are read, one for each of the six water flow equations. The integers determines which discretization scheme is to be used for the convective terms in the Navier-Stokes equations. Different schemes are implemented in the two SSIIM versions:

SSIIM 1:

0: first-order power-law (POW) scheme
1: second-order upwind (SOU) scheme
2: central scheme
3: QUICK scheme

SSIIM 2:

0: first-order power-law (POW) scheme
1: second-order upwind (SOU) scheme
10: QUICK scheme
11: Cubic upwind scheme
12: SMART scheme
13: H-QUICK scheme
14: van Leer scheme
15: Superbee scheme
16: Minmod scheme

Note that the different options only applies to the velocity and turbulence equations. Options 10 and above only applies to the velocity equations. The pressure-correction equation will use a different approach for the discretization. This means that the value of the fourth integer will not affect the computations.

Default: *K 6 0 0 0 0 0 0*

Also note that using a different scheme than the first-order upwind scheme for the turbulence equations usually lead to stability problems.

K 9 **SSIIIM 1 only**. A character is read. If it is Y, then the SIMPLEC method is used instead of the SIMPLE method.

K 10 **SSIIM 1 only**. Solver: Usually, a TDMA solver is used. However, if the *K 10 Y* is given in the *control* file, a Gauss-Seidel solver is used instead.

5.3.5 The *L* data set

L Specification of isoline values for *ContourMap* plot. First, an integer is read, which gives the number of isolines. Then, this number of floats are read. The floats specify the isolines. Example:

L 6 55.0 56.0 57.0 58.0 59.0 60.0

If the geometry has bed levels between 55 and 60 meters, and the user chooses bed levels from the graphics options, a contour map of the bed levels will be displayed. There will be contour lines for each meter, from 55 to 60 meters.

Default: The program finds the maximum and minimum value of the variable in the field, and uses 7 lines located between the values.

If more than 7 lines are displayed, all lines will be black. Otherwise each line will have different colour.

Note that sometimes there may be errors in the contouring, if the contour line and the value are identical. This can often be the case for plotting bed levels. To avoid this problem, add a very small value to the values on the *L* data set. For example, if the above data set is used and there is a problem for the 57.0 contour line because the bed level at one of the grid intersections are 57.0, change the data

set to:

L 6 55.0 56.0 57.0001 58.0 59.9 60.0

Note that the values can be changed by the user from the *Values* option in the *Scale* menu of the *Contour map* figure.

5.3.6 The *M* data set (SSIIM 2 only)

The M data set specifies inflow of a water quality constituent or sediments. A maximum of 9 groups of M data sets can be used. Each group corresponds to an inflow section, specified in the *DischargeEditor*. Two integers are read first. The first integer is an index for the group. The first group has index zero. The second integer is an index for the water quality constituent/sediment size. Zero is the smallest number possible. After the two integers, a float is read. This is the value of the inflow concentration of this parameter.

Example: *M 0 2 0.001*

If sediments are computed: In inflow section 0, the concentration of size 2 is 0.001.

For example, if there are three inflow sections, and five water quality constituents, it will make sense to have 15 *M* data sets. If no *M* data set is given for a particular inflow section and water quality parameter, the inflow is zero. M data sets given for sections with water outflow has no effect on the computation, and should not be used.

The values of the *M* data set does not change over time, unless altered by using *M* data sets in the *timei* file. This is the recommended procedure to model time-varying inflow of water quality components.

It is recommended to model time-varying inflow of sediment concentration by specifying the concentrations in the timei file, without using *M* data sets in the *control* file.

5.3.7 The *N* data set

The *N* data set composes the size fractions of different groups of sediments. Two integers and one float is read. The first integer is an index for the group. The second integer is an index for the sediment size, similar to the first index on the *S* and *I* data sets. The float is the fraction of the size in the group.

The first group has index 0 (zero).

Normally, multiple *N* data sets are used for making a group. For example if there are three groups and five sediment sizes, there should be 15 *N* data sets.

The different sediment groups are distributed in the geometry by using the *B* data sets.

Note that more than one sediment group can only be used in SSIIM 1. In SSIIM 2, only group zero is used over the whole geometry. To use a spatial variation in the grain size distribution in SSIIM 2, the *fracres* file has to be used.

5.3.8 The *B* data set

The *B* data set distributes different sediment groups to different locations of the geometry. The groups are made using the *N* data set.

Five integers are read. The first integer is an index for the group number, similar to the first integer on the *N* data set. The second and third integer are indexes for the cell numbers in the streamwise direction. The fourth and fifth integer are indexes for the cell numbers in the lateral direction.

Example: *B 0 2 6 2 9*

Sediment group no. 0 is placed in the cells from i=2 to i=6 and j=2 to j=9, where i is an integer for the streamwise cell number and j is an integer for the cell numbering in the lateral direction.

If only one group is used, it is possible to give *B 0 0 0 0 0*, which indicates that this group is distributed in all the cells.

5.3.9 The *P* data sets

P 2 Five floating points that give scaling for the graphical presentation. The first three gives scales in streamwise, lateral and vertical direction. The fourth and fifth give movements in left-right and vertical direction. Defaults: 1.0 for the scales, and 0.0 for the movements.

P 3 Four integers that give initial location of the graphical plots in streamwise, lateral and vertical direction, and sediment fraction number.

P 4 A character that indicates initial type of plot is used initially in the graphics windows. The character "*g*" gives the grid, "*v*" gives velocity lines, "*V*" gives velocity vectors, "*c*" gives concentration. Further options are given in Chapter 5.19.

P 6 Minimum and maximum values for blue and red colors in the OpenGL graphics. Two floats are read.

P 10 Integer for the number of global iterations between printing *result* files for time-dependent computations. In SSIIM 2, a number of different files can be written, as given on the *F 329* data set.

P 11 **SSIIM 2 only**. Extra print-out to the *boogie* file for each time step. An integer is read. Depending on the integer, different information is printed.

1: Total amount of water quality constituent 1 for the whole grid
2: Average value of water quality constituent 1 in the surface cells
4: Total number of grid cells, surfaces and points.

Default *P 11 0* (no extra print-out)

P 14 A float is read, which gives a time interval for when a graphic file is automatically saved in the profile and contour plot. The graphic window have to be open and the timer has to be running. This only works for time-dependent calculations. The time interval is given in seconds.

5.3.10 The *Q* data sets

There are two types of *Q* data sets. One is the *Q 0* data set, which gives the name of the variable. The other type specifies the variables and constants in the source terms in the convection-diffusion equations.

Q 0 An integer is first read, corresponding to the equation number. Then a text string of up to 15 character is given. The text is the name of the variable in the equation.

Q (1-..) All other Q data sets have the following in common:

The first integer specifies which source term is used. If the integer is below 1000 or above 3000, the source term is applied for all the cells. If the integer is above 1000, but below 2000, the source term is only applied to the cells closest to the water surface. These terms can typically be used for specification of fluxes across the water surface. If the integer is above 2000 but under 3000, the source term only applies to the cells closest to the bed.

The second integer after the *Q* is an index equal to the number of the equation the source term is applied to.

In the following, note that this is not repeated, and the two fist integers are not described further.

Q 1 The second number is a float, giving the value of a constant source.

Q 2 The second number is an integer. This is an index for the variable in the source term. The third number is a float, giving a coefficient which is multiplied with the variable.

Example: *Q 2 1 2 0.05*

This means that a source term for equation 1 is used, and the source term is 0.05 multiplied with the value of variable 2.

Q 3 The second number is an integer. This is an index for the first variable in the source term. The third number is an integer, giving the second variable in the source term. The fourth number is a float, which is multiplied with both variables.

Example: *Q 3 1 2 1 0.04*

This means that a source term for equation 1 is used, and the source term is 0.04 multiplied with the value of variable 2, multiplied with the value of variable 1 (the same variable as calculated for this source term).

Q 11 Fall velocity data set. This is a special data set to include the effect of the fall velocity of a water quality constituent, for example sediments or algae. A constant fall velocity is given. Note that calculating algae with variable fall velocity as a function of light irradiance, for example the *Q 151 / Q 221* data sets can be used instead.

The second parameter is a float, which is the fall velocity in meters/second. A positive number denotes a rise velocity, while a negative number denotes a fall velocity in downwards direction.

Example: *Q 11 2 -0.0001*

Variable no. 2 has a fall velocity of 0.1 mm/second.

Q 42 SSIIM 2 only. Special data set to calculate algae growth where there is only one species of algae, and this is only growth-limited by light. Four floats are read. The first two floats are constants in the regression formula for the vertical attenuation coefficient as a function of the algae concentration. The last two floats are the coefficients *c0* and *c1* in the formula for algae growth.

Q 51 SSIIM 2 only. Special data set for fall velocity for dinoflagellates as a function of irradiance. Five floats are read after the control integer. The two first are coefficients in the formula for the light attenuation coefficients. The third is the optimum irradiance. The fourth is the maximum fall/rise velocity in m/s. The fifth is the difference between optimum and actual irradiance when the fall/rise velocity is maximum.

Example: *Q 51 1 0.45 4.8 100.0 0.01 100.0*

The algae concentration is in variable number 1.

Q 113 SSIIM 2 only. Special data set to calculate light history, if more than one algae species or sediment variable contribute to the light shading:

integer 1: pointer to irradiance variable
float 1: averaging time period in seconds

Q 121 SSIIM 2 only. Special data set to calculate predatation. This data set must be used for both the phytoplankton and the zooplankton.If phytoplankton is calculated, the grazing rate is negative. If zooplankton is calculated, the grazing rate is positive.Note that if zooplankton is calculated, the coefficient also includes the grazing efficiency and possible conversion between phytoplankton and zooplankton units.

Example: *Q 121 2 4 -0.01 1.067*

Algae is calculated as variable no. 2, zooplankton as variable no. 4. The grazing rate is 0.01 and the temperature coefficient is 1.067.

Q 122 SSIIM 2 only. Special data set for reduction of patogens from light. One integer and two floats are read. The second integer is a pointer to the irradiance variable. The first float is the proportionality constant for decrease of patogens. The second float is a temperature constant.

Example: *Q 122 1 3 -0.001 1.067*

Pathogens are calculated as variable no. 1 and irradiance as variable no. 3. The proportionality constant is -0.001 and the temperature coefficient is 1.067.

Q 123 SSIIM 2 only. Special data set for sorption, containing one integer and two floats. The integer is an index to the sediment variable. The first float is the absorption coefficient. The second float is the fall velocity of the sediment.

Example: *Q 123 2 4 0.1 0.005*

Variable no. 2 is adsorped to variable no. 4, with the adsorption coefficient 0.1.
The fall velocity of variable 4 is 5 mm/second.

Q 131 SSIIM 2 only. Special data set for calculation of algae fall velocity from density variable

integer1: pointer to algae density
float 1: algae diameter in meters, from *Q 221*
float 2: form resistance (around 1.0-1.15), from *Q 221*
float 3: temperature in degree Centigrade

Q 132 SSIIM 2 only. Special data set for calculation of light history from one species of algae. The light history is calculated by a formula and fixed.

integer 1: pointer to algae concentration
float 1: a - regression constant in formula for specific vertical attenuation coefficient, as *Q 42*
float 2: b - regression constant in formula for specific vertical attenuation coefficient, as *Q 42*
float 3: averaging period in seconds, for example: 86400.0 for 24 hours

Q 133 SSIIM 2 only. Special data set for calculation of light history from one species of algae. The light history is calculated as a passive contaminant.

integer 1: pointer to algae concentration
float 1: a - regression constant in formula for specific vertical attenuation coefficient, as *Q 42*
float 2: b - regression constant in formula for specific vertical attenuation coefficient, as *Q 42*
float 3: averaging period in seconds, for example: 86400.0 for 24 hours

Q 151 SSIIM 2 only. This is a special data set to calculate the density of algae in a lake. The second number is an integer, which is an index for the variable number which is the algae concentration. The algae concentration is used when calculating the light transmission. After the second integer, five floats are read. The first float is the light transmissivity. The second, third and fourth float are coefficients *c1,c2* and *c3* in the formula for algae density. The fifth float is the half-saturation irradiance for maximum rate of density increase. This is also used in the density formula.

Note that the convection-diffusion equation is not solved for the algae density, but from a user point of view, this variable is similar to other variables.

Example: *Q 151 1 2 1.0 2.0 3.0 4.0 5.0*

Algal density is in variable no. 1, and algae concentration is in variable no. 2. The light transmissivity is 1.0, and the coefficients in the density equations are: *c1* = 2.0, *c2* = 3.0, *c3* = 4.0. The half-saturation irradiance coefficient is 5.0. Note that these numbers are arbitrarily chosen, and may be unphysical.

Also note that if a *Q 151* data set is present in the *control* file, and the *timei* file is read for time-dependent calculations, an extra float is read as the last number of each line. The float is the irradiance.

Q 161 SSIIM 2 only. Special data set to calculate algal density for cyanobacteria. The second number is an integer, which is an index for the variable number which is the algae concentration. The algae concentration is used when calculating the light transmission. After the second integer, five floats are read. The first float is the light transmissivity. The second, third and fourth float are coefficients *c1,c2* and c3 in the formula for algae density. The fifth float is the half-saturation irradiance for maximum rate of density increase. This is also used in the density formula.

Note that the convection-diffusion equation is not solved for the algae density, but from a user point of view, this variable is similar to other variables.

Example: *Q 161 1 2 0.67 0.087 2.0 3.0 4.0 5.0*

Algal density is in variable no. 1, and algae concentration is in variable no. 2. The coefficients in the equation for light transmissivity are 0.67 and 0.087, and the coefficients in the density equations are: *c1* = 2.0, c2 = 3.0, c3 = 4.0. The half-saturation irradiance coefficient is 5.0. Note that these numbers are arbitrarily chosen, and may be unphysical.

Also note that if a *Q 161* data set is present in the *control* file, and the *timei* file is read for time-dependent calculations, an extra float is read as the last number of each line. The float is the irradiance.

Q 221 SSIIM 2 only. This a special data set that calculates the fall velocity of algae in a lake. The second and third number are integers. The second number points to the variable number of the algae density. The third integer points to the variable number of the temperature. Then two floats follow. The first float is the algae diameter in metres. The second float is a form resistance coefficient, usually around 1.0.

Example: *Q 221 2 1 0 0.00001 1.0*

The algae concentration is variable no. 2, the algae density is variable no. 1, and the temperature is variable no. 0. The algae diameter is 0.00001 meters and the form resistance coefficient is 1.0.

Q 252 SSIIM 2 only. Special data set to calculate algae growth in case of only one nutrient + irradiance limiting the growth:

integer 1: integer pointing to algae concentration
integer 2: pointer to light irradiance variable
integer 3: pointer to nutrient variable

float 1: c_0 - formula for growth rate, *k*, irradiance.
float 2: c_1 - formula for growth rate, *k*, irradiance.
float 3: *kmax* - maximum growth rate
float 4: *Ks* constant for nutrient
float 5: temperature coefficient

Q 261 SSIIM 2 only. Special data set for nutrient depletion from algae growth, for multiple algae species limiting the light, and one nutrient. Three integers and seven floats are read:

integer 1: integer pointing to nutrient variable
integer 2: integer pointing to light variable
integer 3: integer pointing to algae variable
float 1: c_0 - formula for growth rate, *k*, irradiance.
float 2: c_1 - formula for growth rate, *k*, irradiance.
float 3: kmax - maximum growth rate
float 4: *Ks* constant for the nutrient being calculated
float 5: temperature coefficient
float 6: fraction of nutrient in algae growth

Q 281 SSIIM 2 only. Special data set for algae growth, with phosphorus, nitrogen and light as the limiting variables:

integer 1: integer pointing to algae variable
integer 2: integer pointing to phosphorous variable
integer 3: integer pointing to nitrogen variable
float 1: a - regression constant in formula for specific vertical attenuation coefficient
float 2: b - regression constant in formula for specific vertical attenuation coefficient
float 3: c0 - formula for growth rate, k, irradiance.
float 4: c1 - formula for growth rate, k, irradiance.
float 5: kmax - maximum growth rate
float 6: Ks constant for phosphorous
float 7: Ks constant for nitrogen
float 8: temperature coefficient, Kt

The first four floats are similar to the *Q 42* data set.

Q 282 SSIIM 2 only. Special data set for calculation of algae density from one species of algae:

integer 1: integer pointing to algae density
integer 2: pointer to algae concentration
integer 3: pointer to light history
float 1: a - regression constant in formula for specific vertical attenuation coefficient, as *Q 42*
float 2: b - regression constant in formula for specific vertical attenuation coefficient, as *Q 42*
float 3: c1 - formula 5, SCUM, as *Q 151*
float 4: c2 - formula 5, SCUM, as *Q 151*
float 5: c3 - formula 5, SCUM, as *Q 151*
float 6: Ki - half-saturation irradiance, formula 5, SCUM, as *Q 151*

float 7: minimum algae density
float 8: maximum algae density

Q 291 SSIIM 2 only. Special data set for nutrient depletion from algae growth, for two nutrients and one algae shading the light. Two integers and nine floats are read:

integer 1: integer pointing to nutrient parameter
integer 2: integer pointing to algae variable
integer 3: integer pointing to the other nutrient variable
float 1: a - regression constant in formula for specific vertical attenuation coefficient
float 2: b - regression constant in formula for specific vertical attenuation coefficient
float 3: c0 - formula for growth rate, k, irradiance.
float 4: c1 - formula for growth rate, k, irradiance.
float 5: kmax - maximum growth rate
float 6: Ks constant for the nutrient being calculated
float 7: Ks constant for the other nutrient
float 8: temperature coefficient
float 9: fraction of nutrient in algae growth

The data set is used for both nitrogen and phosphorous. It is similar to Q 281, but the last float is the fraction of the algae growth.

Q 361 SSIIM 2 only. Special data set to calculate algae growth in case of two nutrients+light limiting the growth:

integer 1: integer pointing to algae concentration
integer 2: pointer to light irradiance variable
integer 3: pointer to phosphorous variable
integer 4: pointer to nitrogen variable
float 1: c0 - formula for growth rate, k, irradiance.
float 2: c1 - formula for growth rate, k, irradiance.
float 3: kmax - maximum growth rate
float 4: Ks constant for phosphorous
float 5: Ks constant for nitrogen
float 6: temperature coefficient

Q 371 SSIIM 2 only. Special data set for nutrient depletion from algae growth, for multiple algae species limiting the light, and two nutrients. Three integers and seven floats are read:

integer 1: integer pointing to nutrient parameter
integer 2: integer pointing to light variable
integer 3: integer pointing to algae variable
integer 4: integer pointing to the other nutrient variable
float 1: c0 - formula for growth rate, k, irradiance.
float 2: c1 - formula for growth rate, k, irradiance.
float 3: kmax - maximum growth rate
float 4: Ks constant for the nutrient being calculated

float 5: Ks constant for the other nutrient
float 6: temperature coefficient
float 7: fraction of nutrient in algae growth

The data set is similar to *Q 291*, except for the extra integer pointing to the light irradiance, and the omission of the attenuation coefficients.

Q 1001 The second number is a float, giving the value of a constant source.

Q 1002 The second and third numbers are floats. The source term is:

Source = float1 * (float2 - variable)

Example: *Q 2 1 0.0005 20.0*

Source1 = 0.0005 * (20.0 - variable1)

This term can be used for calculation of temperature fluxes across the water surface, where the first float is the heat exchange coefficient for the water surface and the second float is the air temperature.

Q 1003 The second number is an integer. This is an index for the first variable in the source term. The third number is an integer, giving the second variable in the source term. The fourth number is a float, which is multiplied with both variables.

Example: *Q 3100 1 2 1 0.04*

This means that a source term for equation 1 is used, and the source term is 0.04 multiplied with the value of variable 2, multiplied with the value of variable 1 (the same variable as calculated for this source term)

Q 1012 The second number is an integer. This is an index for the variable in the source term. The third number is a float, giving a coefficient which is multiplied with the variable.

Example: *Q 1012 1 2 0.05*

This means that a source term for equation 1 is used, and the source term is 0.05 multiplied with the value of variable 2.

Q 1060 Special data set to calculate temperature flux at the water surface. Six floats are read:

float 1: multiplication factor, *B*, for irradiance from the timei file (1.0)
float 2: a coefficient, *A*, for light attenuation (0.5-0.7)
float 3: air vapour pressure, eair (mmHg)
float 4: reflection coefficient, RL (0.03)
float 5: water emissivity, e (0.97)
float 6: Bowen's coefficient, c1 (0.47 mmHg/C)

Q 1102 Special data set to calculate gas transfer at the water surface. The data set has two floats as parameters: cair and a coefficient, r, which is multiplied with the eddy-viscosity to give the effective diffusion. The data set is only applied to the cells bordering the water surface.

Q 2001 The second number is a float, giving the value of a constant source.

Q 2002 The second number is an integer. This is an index for the variable in the source term. The third number is a float, giving a coefficient which is multiplied with the variable.

Q 2003 The second number is an integer. This is an index for the first variable in the source term. The third number is an integer, giving the second variable in the source term. The fourth number is a float, which is multiplied with both variables.

Q 2030 Special data set to calculate resuspension, where three floats are read. The first float is the critical shear stress for initiation of resuspension. The second integer is the coefficient *a* in the resuspension equation, being proportional to the shear stress surplus raised to the third coefficient. The critical shear stress is given in Pascal.

Example: *Q 2030 3 0.3 0.1 1.5*

The resuspension is calculated for variable no. 3, and the critical shear stress is 0.3 Pa.

Q 6100 **SSIIM 2 only**. Special data set for calculating irradiance when there are more than one algae species or sediment concentration. The data set reads six integers and ten floats. The first integer is the number of algae species. The following integers are indexes for the variable numbers of the algae. Then ten floats are read, which are pairs of coefficients for the light attenuation curve.

Example: *Q 6100 9 2 5 6 0 0 0 0.07 0.2 0.06 0.23 0.0 0.0 0.0 0.0 0.0 0.0*

Here, variable no. 9 is the light irradiance. Two species of algae is used: variable no. 5 and no. 6. The light transmissivity coefficients are 0.07 and 0.2 for the first algae species and 0.06 and 0.23 for the second algae species.

Note that the component reducing the light does not have to be an algae. It is also possible to specify for example an inorganic sediment.

5.3.11 The *S* data set

The S data sets gives the size and fall velocity of the sediments. An integer is first read, indicating the size group. Then the diameter in meters are given and then the fall velocity in m/s.

Example: *S 1 0.001 0.06*

Sediment size 1 has a diameter of 1 mm, and a fall velocity of 6 cm/s.

Note that the coarsest sediment size should be number 1, and then the finer sizes should follow with the

finest size having the highest index.

5.3.12 The *T* data set

T Title field. The following 30 characters are used in the graphics.

5.3.13 The *W* data sets

W 1 Stricklers number, discharge and downstream water level. This data set must be present in the file. The parameters given here are used to generate the water level for the calculations using a standard backwater calculation.

Default values for SSIIM 2: *W 1 50.0 1.0 1.0*

Note that the Strickler value *M* is *1.0/n*, where n is the Manning's number.

W 2 Integers identifying which cross-sections are used in the initial backwater water surface computation. First, an integer is read, giving the number of cross-sections. Then, the number of each cross-section is given.

For example, if the grid has 20 cross-sections, and three sections are used: the first (number 1), the last (number 20) and one in the middle (number 10), the following data set is given:

W 2 3 1 10 20

The water elevation for the other cross-sections in between will be linearly interpolated.

W 4 **SSIIM 1 only**. Specification of extra walls for the multi-block water flow module. Seven integers have to be given for each wall. There can be up to 29 walls, and each wall is described on one W 4 data set.

The variable names are:

W 4 dir posneg node a1 a2 b1 b2

The first integer, *dir*, indicates the plane. 1 is the *j-k* plane (cross-section), 2 is the *i-k* plane (longitudinal section) and 3 is the *i-j* plane (seen from above).

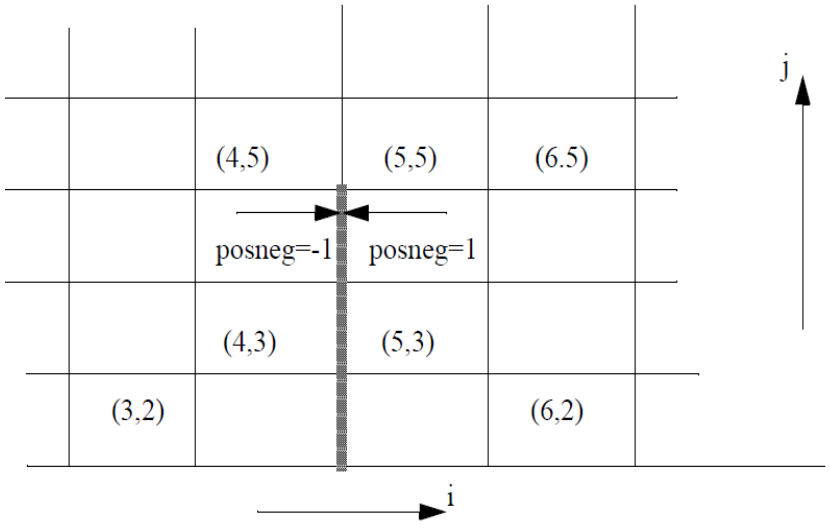
The second integer, *posneg*, indicates which of the sides of the cell is calculated as a wall. Three possible options exist: 1, -1 or 0. If 0 is given, a previously set wall is deleted. If the index is 1, the wall is calculated on the wall in the direction of declining cell indexes. If -1 is given, the wall is calculated in the direction of increasing cell indexes. This is further explained in Fig. 5.3.1.

The third integer is the number of the node plane.

An example is given in Fig. 4 below. The figure shows the *i-j* plane (the grid seen from above). The wall is to be given in cells where *i*=4 (between cross-section no. 3 and 4). If the second integer, *posneg*, is 1, then wall laws are applied on cross-section no. 3, between cell 3 and cell 4, in the negative i-direction. If *posneg* = -1, then the wall laws are applied on cross-section no.4, between cell no. 4 and 5, in the positive i-direction.

The following integers are indexes *a1 a2 b1 b2,* which gives the two-dimensional coordinates for the corner points of the part of the plane that is described. The four variables are similar to the variables with the same name on the *G 7* data set.

Note that if an internal wall is used, where water is flowing on both sides of the grid line, then wall laws must be declared on both sides of the wall, and two *W 4* data sets must be used.



Example: If the groyne given in Fig. 4 is to block the water from the bed to the water surface and there are four cells in the vertical direction (cell no. 2 to 5), the following data sets have to be given:

W 4 1 1 4 2 4 2 5
W 4 1 -1 5 2 4 2 5

Two *W 4* data sets have to be given, one for each side of the groyne. The first is for the left side (Fig. 4), and the second is for the right side.

W 5 **SSIIM 1 only**. Different Strickler's values than the default value for cross-sections. An integer is first read, which tells how many cross-sections are read. Then an integer and a float is read for each cross-section. The integer tells which cross- section is changed, and the float tells the Strickler's value. Several *W 5* data sets can be used.

Note that the Strickler's value in the most upstream cross-section will be used on a reach between two cross-sections. The Strickler's values are the inverse of the Mannings n values: M=1/n.

W 6 NoMovePoint - a point which is used in the *Grid Editor*. Two integers are read, which is the numbers of the i and j grid lines. The intersection of these lines are not moved by the elliptic grid generator. One *W 6* data set is required for each *NoMovePoint*. Maximum 19 999 points can be used. The *W 6* data set is usually generated by the *Grid Editor*. When the *control.new* file is written, it contains the W 6 data sets. These can be copied to the *control* file.

W 7 Attraction point used in the *Grid Editor*. Each *W 7* data set represents attraction to one grid line or point. Maximum 1999 attraction points can be used. An integer is read first which tells the type of attraction. The following options are given:

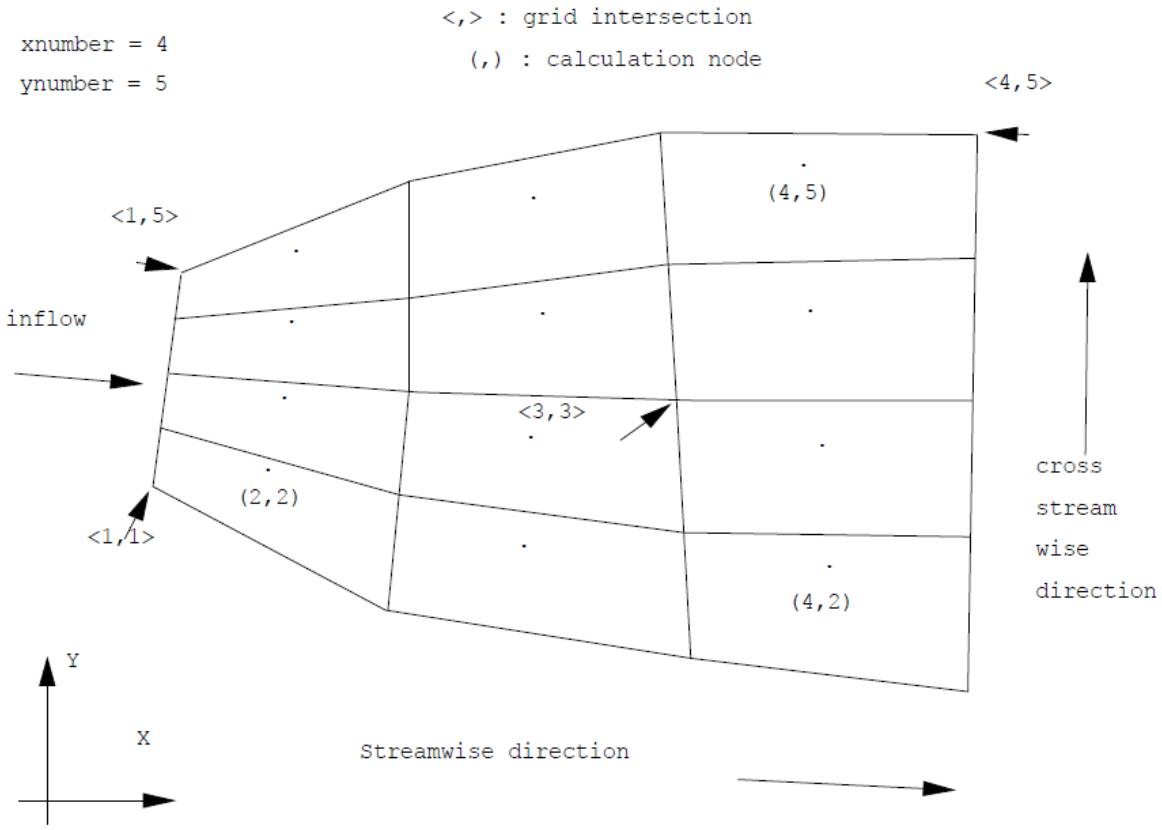
0: Point attraction in i-direction
1: Point attraction in j-direction
2: Line attraction in i-direction
3: Line attraction in j-direction

Then two integers are read, that tell which grid line intersection the attraction is towards. For the line attraction, only one of the integers are used. Then the two attraction parameters are read, which are floats.

The *W 7* data set is normally generated by the *Grid Editor*.

5.4 The *koordina* and *koomin* files

The *koordina* file describes the bed of the geometry with a structured grid (SSIIM 1). An example is show in the figure below. The grid can be made using a map, a spreadsheet or the *GridEditor*.



The necessary input data is the *x*, *y* and *z* coordinates of the points where the grid lines meet. The format of the data is given below.

i j x y z

An example:

1 1 0.34 0.54 0.11
1 2 0.35 0.66 0.12
...

The first two numbers are integers, while the following three are floats. The numbers are read in a free format, which means that the distance between them does not matter. The sequence of the points are not important, as long as all points are included. This is not controlled by the model, so the user must do the check by looking at the grid in the graphic modules of the program.

If a tunnel is simulated, or the user wants to specify the water surface, an additional floating point number is read for each line. This gives the top level for each grid intersection. An example:

1 1 0.34 0.54 0.11 1.21
1 2 0.35 0.66 0.12 1.33
...
To make SSIIM read the last float, the *K 2* data set in the *control* file must be: *K 2 0 0*

Some words about indexing and numbering of grid lines and cells. The variable names for the number of grid lines in the three directions are:

xnumber : number of cross-sections
ynumber : number of longitudinal lines
znumber : number of horizontal planes

The numbering of the grid lines goes from 1 to *xnumber* in the streamwise direction, and similarly for the other two directions.

However, the grid lines define cells between the grid lines. The variables are calculated in the center of each cell. This means that a numbering system for the cells is also required. The word node is often used for the center of a cell.

From a geometrical view of the grid, it is observed that the number of lines always exceeds the number of cells by one in each direction. When the arrays are defined, it is therefore a choice for the programmer to start the numbering of the cells on one or two. The choice that is made in SSIIM is that the numbering starts on two. This means that the cell that is defined by grid lines i=1 and i=2 and j=1 and j=2 has the number (2,2). Cell number (1,1) does not exist. The numbering of the cells is also shown in Fig. 1. The numbering of the grid lines is shown with the <,> sign, while the numbering of the calculation nodes is shown with the (,) sign. The grid is non-staggered.

The data on the *koordina* file defines a surface. It is possible to make a file with exactly the same format and call it *koomin*. This surface is then used as a minimum elevation surface for bed changes. The bed will not be lowered under this surface.

If SSIIM terminates right after startup and the *boogie* file contains the following message: Error, negative areas for cell i=13, j=2, or some other combinations of i and j, then there is an error in the *koordina* file. The indexes denote the cell number, so for i=13, j=2, the x and y coordinates for the following grid line intersections should be checked: (13,2); (13,1); (12,2) and (12,1).

SSIIM 2

The *koordina* file used in SSIIM 2 will always include the water surface location, meaning each line has two integers and four floats.

5.5 The *unstruc* file (SSIIM 2 only)

The geometry data is stored in the unstruc file. This file contains the coordinates of all grid line intersections, which cells are connected with other cells, which surfaces are connected to which cells etc. It also contains information about inflow/outflow of water and water quality constituents.

Because of the complexity of the file, it is not possible to generate this file using an editor or a spreadsheet. This file must be generated by SSIIM 2.

Note that the first line in the file gives the grid size for allocation of arrays. The first integer is a number below 10, for the files generated with the newest versions of SSIIM 2. The second number is the number of grid cells. The third number is the number of surfaces. The fourth number is the number of blocks in the grid. The fifth number is the number of connections between the blocks. The sixth integer is the number of connection surfaces between the blocks. The seventh integer is the number of outer surfaces on the nested blocks. The last integer on the line is the number of points in the grid.

This information can be used to set the size of the arrays allocated by SSIIM 2 on the *F 65* data set.

Example: *1 22500 75600 1 0 0 0 308041*

The line specifies that the *unstruc* file is generated by a newer version of SSIIM 2, since the first integer is below 10. The grid has 22500 cells, 75600 surfaces and 308041 points. It consists of only one block, and there are no connections between blocks (since it is only one block) and no nested surfaces (since there are no nested blocks).

In *unstruc* files generated by older versions of SSIIM 2, the first integer is the number of points in the grid. This will always be above 10. Then there will be one less integer on the first line, compared with the *unstruc* file produced by the newest SSIIM 2 versions. The newest SSIIM 2 version can read both formats and is therefore backwards compatible with old *unstruc* files.

Automatic grid changes

The default water surface elevation is completely horizontal when starting to make a grid using SSIIM 2. When modelling a river, one often would start with a sloping water surface. Also, one might want to start with a dry bed that can be wetted later. The unstruc file must also contain some information about the grid in the dry areas. The initial grid of the unstruc file therefore must cover the whole geometry that can be wetted, which means a fairly large water surface elevation must be used. Starting the computation with a lower water surface is then done by using the *F 112* data set. If the integer on this

data set is set to 1, then the grid is regenerated right after the unstruc file is made. Before the regeneration, the *koordina* file is read. In the *koordina* file, the water surface elevation can be specified, and this can be a sloping surface. The water surface can also be below the bed, giving a startup with a partially dry geometry.

5.6 The *geodata* file

This file contains a number of *x*,*y* and *z* coordinates. An example is shown below:

E 2.2 3.3 3.4
E 4.5 3.3 2.2
E 3.3 4.2 1.2
Z 3.0 3.0 3.0

The letter *E* is used for counting the number of points. The letter Z is used for the last line in the file. The numbers on this line are not used.

The purpose of this file is to use geometrical data that has been obtained from the field, a digitized map or a GIS system.

The file is used in the *GridEditor*, to display the points in the file when generating the grid. The View option of the menu and the *geodata* points option in the pull-down menu activates this. The grid points are displayed with different colors according to which level they are.

The second use for this file is also in the *GridEditor*. It is then used in the Make bed interpolations for generating the z values for the bed of the grid. A linear interpolation procedure is used. The procedure is further described in Chapter 4.3.

The *GridEditor* in SSIIM 2 makes it possible to add new *geodata* points graphically. Afterwards, the total set of points can be written to a new *geodata* file. Similarly, points can be deleted. This is convenient for studies investigating changes in the geometry. Note that only 498 new *geodata* points can be added at once. If you want to add more points, write the *geodata* file to the disk, and then read it back again.

Also note that even if SSIIM 1 is used for the water/sediment flow computation, it is still possible to use SSIIM 2 to modify the *geodata* file, and read it by SSIIM 1 afterwards. SSIIM 2 has more options to modify the *geodata* file than SSIIM 1.

5.7 The *bedrough* file

This file is used to give a roughness height to individual bed cells. Values in this file overrides the value calculated from Manning-Strickler's coefficient, and the value given on the F 16 data set. On each line a character, two integer and a float are given. The first character is a B, and the two following

integers are indexes for the bed cell. The float is the roughness in meters. An example is given below:

B 19 2 0.001
B 19 3 0.001
B 19 4 0.001

5.8 The *porosity* and *vegdata* files

Note: When calculating porosity, use a *P* on the *F 7* data set in the *control* file. When using the *vegdata* file, the *F 115* data set has to be included in the *control* file

The *porosity* file is only used in SSIIM 1. The *vegdata* file is used in both SSIIM 1 and SSIIM 2.

The two files are used when the bed of the river is covered by stones or vegetation, introducing a sink term for the velocities.

The *porosity* file (SSIIM 1 only)

The file describes the location and magnitude of the porosity or vegetation in the geometry. An example of a porosity file is given below:

P 17 6 3.349774 3.399189 3.450101 3.499517 0.000000 0.700000 0.833333 1.000000
P 17 7 3.358273 3.413603 3.470610 3.525940 0.000000 0.653846 0.807692 1.000000
P 17 8 3.403323 3.426084 3.449536 3.472297 0.000000 0.642857 0.785714 1.000000

First, the character *P* is read. Then two indexes for the *i* and *j* number of the bed cell is read. Then four vertical levels are read, which have the same zero reference as the *koordina* file. The porosities in each of these levels are then read.

The porosity file can be made from a *koordina* file and a *geodata* file. The module that does this is activated from the main menu of the user interface, from File and Make porosity file in the pull-down menu. The procedure goes through each element and used the points in the *geodata* file to obtain the data. The procedure is described in more detail in Chapter 2.3.

The *vegdata* file

The vegetation is modelled as a number of vertical cylinders in each cell. A drag formula is used to determine the force between the water and the stems. The drag formula computes the sink in the velocity equations as proportional to the velocity squared. If a different formula is to be used, it can be coded in the vegdll.dll file.

The vegdata file is similar to a porosity file, in that each line describes one bed cell and each line starts with a letter and then two indexes for the cell is given. Then four levels are given.

There are different types of vegdata set. The types are identified by the first letter in the line.

A V data set is similar to the P data set, except instead of the porosity, four vegetation values have to be given. The vegetation values are defined by multiplying the following three parameters:

1. The drag coefficient for the vegetation stems. This is usually around unity
2. The diameter of the stems (in meters)
3. The number of stems in each cell.

As an example, say there are five stems in each cell, with diameter 7 cm, and the stems are circular with a drag coefficient of 1.0. The vegetation parameter becomes: 1.0x.07x5 = 0.35.

An A data set is similar to a V data set, except the number of stems pr. square meter is given instead of number of stems in each cell.

Example:

A 76 16 37.05 37.20 37.35 37.55 3.0 1.0 1.2 0.5
A 76 17 37.05 37.20 37.35 37.65 3.0 1.0 0.8 0.5
A 76 18 37.05 37.20 37.25 37.75 4.0 1.0 1.1 0.5
...

A *B* data set is similar to an *A* data set, but 4x4 more floats are read on each line. First, four numbers are read, giving the number of stems pr. square meter for each of the four levels. Then four numbers are read giving the diameter of the stems. The next four numbers are the drag coefficients. The final four numbers are empirical parameters in the epsilon equation. The additional terms are used for source terms in the *k* and ε equations.

The vegetation parameter can be seen in the map graphics. This is a good way of testing that the correct values are given in the input file.

Using SSIIM 2, there is only one index for each cell. In the *vegdata* file, two indexes are given. The two indexes corresponds to the indexes used in a structured grid. This system is necessary as in SSIIM 2, as the numbering of the cells changes over time during wetting and drying.

If the vegetation changes over time, it is possible to describe the vegetation at several times in the *vegdata* file. To do this, a *T* data set has to be given between each group of vegetation data sets. The T data set also has to have a floating point number, which will be the time when the data set is valid. The program will interpolate between the different times given in the *vegdata* file.

When time-dependent changes in the vegetation is computed, then the *F 201* data set has to be used in the *control* file. Also an *U* data set has to be used in the vegdata file. The *U* data set has to have the same integers as on the *F 201* data set.

Example:

The *control* file: contains *F 201 1 4 3* (three times)

The *vegdata* file:

U 1 4 3
T 0.0
A 76 16 37.05 37.20 37.35 37.55 3.0 1.0 1.2 0.5
A 76 17 37.05 37.20 37.35 37.65 3.0 1.0 0.8 0.5
A 76 18 37.05 37.20 37.25 37.75 4.0 1.0 1.1 0.5
... (all A data sets for this geometry and time= 0.0 seconds)
T 10000.0
A 76 16 37.05 37.20 37.35 37.55 5.0 2.0 1.2 0.5
A 76 17 37.05 37.20 37.35 37.65 5.0 2.0 0.8 0.5
A 76 18 37.05 37.20 37.25 37.75 5.0 2.0 1.1 0.5
.. (all A data sets for time=10000 seconds)
T 30000.0
A 76 16 37.05 37.20 37.35 37.55 3.0 1.0 1.2 0.5
A 76 17 37.05 37.20 37.35 37.65 3.0 1.0 0.8 0.5
A 76 18 37.05 37.20 37.25 37.75 4.0 1.0 1.1 0.5
.. (all A data sets for time=30000 seconds)

5.9 The *innflow* file (SSIIM 1 only)

This file is used to read velocities in three directions for the upstream boundary condition. The program searches for this file, and uses the data on the file if it exists. If the file does not exist, a warning message is written to the boogie file, and the program proceeds normally.

On each line the velocities in a cell of the upstream cross-section are given. First, the character E is written. Then the indexes j and k (horizontal and vertical) are given. Then the velocity components in the *x*,*y* and *z* directions are given. An example is given below:

E 2 2 0.299115 0.023009 0
E 2 3 1.79469 0.138055 0
E 2 4 1.9941 0.153394 0
E 2 5 2.19351 0.168733 0

The file does not have to contain values for all the nodes. The normal initialization procedures are applied first, and then the *innflow* file is read. The nodes that are not present in the *innflow* file will keep the values from before the file was read.

It is also possible to specify k and ε in the *innflow* file. Then each line should start with a *D* instead of an *E*, and the values of k and ε should be given after the velocities.

5.10 The *result* file

This file contains the results from the water flow calculations, with velocities, pressure and turbulence. Note that although the same variables are written to the SSIIM 1 and SSIIM 2 versions of the file, the two versions are different in structure. This is due to the different grid structures in SSIIM 1 and 2. The result files from SSIIM 1 and SSIIM2 are therefore not compatible with each other.

The *result* file is written when the prescribed number of iterations have been calculated or when the solution has converged. The results are velocities in three dimensions, k, ε, pressure, and the fluxes on all the walls of the cells. The data from this file is used as input for the sediment flow calculations. This file can also be read when the user wants to start the water flow calculations from where the *result* file was last written (hot start).

An example of a *result* file for SSIIM 1:

Results from SSIIM - flow, iter = 12910
Residuals: 0.000732 0.000588 0.000002 0.000003 0.001000 0.000000
Roughness : 0.050000
C 54 9 11
i j k u v w k e f1 f2 f3 p
D 1 1 1 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00
D 1 1 2 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00
D 1 1 3 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00 0.00000000e+00
.....

D 2 4 7 6.31143968e-01 2.02894592e-01 -6.80367016e-05 6.47305125e-03 3.85539263e-04 3.47858729e+03 -5.19507052e+02 1.39776552e+03 1.91355310e+02
D 2 4 8 6.38189711e-01 2.05198514e-01 -2.09522025e-04 6.40727451e-03 3.13804122e-04 3.54203761e+03 -5.25291012e+02 1.09548199e+03 1.91350056e+02
D 2 4 9 6.42687814e-01 2.06670571e-01 -3.70305526e-04 6.37079494e-03 2.71714390e-04 3.58421958e+03 -5.28978103e+02 7.51732364e+02 1.91343817e+02

The first lines give the residuals, the roughness and the grid size. Then each line gives the nine values for one cell. The letter *D* starts the line, then the three indexes for the cell. Then the three velocities, the k and e values. Then the fluxes in the three directions and finally the pressure. All the parameters are placed on one line in the file, although this is not shown above because the line was too long.

A commonly asked question is the meaning of the values in the cells with index 1. The first cell has index 2. The answer is that the index 1 indicates the values at the boundary. Or in a cell at the wall, with zero thickness. The velocity in these cells will usually be zero, unless there is water inflow or outflow.

An example of a result file for SSIIM 2:

Results, iter = 3601
Residuals: 0.054663 0.079991 0.018223 0.029072 5.240989 218.573547
Roughness : 0.005000
U 16316 11940 39679 1 0 0
i u v w k e p
C 1 5.20752712e-002 3.87287893e-002 -2.91152289e-002 1.83900666e-004 2.20008542e-004 6.98685775e+001
C 2 -2.97928650e-003 1.18274871e-002 -2.83168656e-002 4.95138596e-005 1.79039199e-005 6.98566087e+001
C 3 -2.34130748e-003 1.18835706e-002 -2.32318333e-002 2.81046242e-005 1.03435021e-005 7.16544156e+001
C 4 -4.91827925e-003 3.44957829e-002 -1.59890336e-002 5.50987357e-005 3.38688381e-005 7.04038680e+001
C 5 -9.62809076e-003 5.08444254e-002 -1.13473535e-002 7.34700051e-005 1.08660059e-004 6.95710922e+001
C 6 -4.36046706e-003 -4.54215010e-002 -2.87338762e-004 1.13683579e-004 4.87075237e-004 6.32869612e+001
C 7 -4.54495962e-003 -4.54039464e-002 -2.24038016e-004 2.32742813e-004 2.86840184e-004 6.32996242e+001
.....
F 25735 4.35128401e-002
F 25736 -4.35876127e-002
F 25737 0.00000000e+000
F 25738 0.00000000e+000
F 25739 0.00000000e+000
F 25740 1.61427895e-001
F 25741 9.94855359e-002
F 25742 0.00000000e+000
F 25743 0.00000000e+000
F 25744 1.27727494e-001
F 25745 1.46505934e-001
F 25746 0.00000000e+000
..

Similar to the result file for SSIIM 1, the first lines give the residuals, the roughness and the grid size. The *U* data set gives the number of points, number of cells and number of surfaces in the grid. Then the number of blocks, connections and connection surfaces are given. After the *U* data set, the water velocity parameters are given for each cell. Each line gives the values in one cell. The line starts with the letter *C* starts the line, then the number of the cell is given in the unstructured grid. Then the three velocities, the *k* and ε values and the pressure for this cell is given. After all the data for the cells, the fluxes on all the surfaces are given. Each line gives a flux for one surface. The line starts with the letter *F*. Then the number of the surfaces is given. And then the flux is given, in kg/s of water.

All the results are given in SI units, so that for example the velocities are in meters/second, turbulent kinetic energy is given in m^2/s^2, epsilon is given in m^2/s^3 and the pressure is in Pascal, or Newton/m^2.

5.11 The *conres/con2res* files

The conres and *con2res* files contains the sediment concentrations in the grid. The *conres* file is used in SSIIM 1 and the *con2res* file is used in SSIIM 2.

The conres files is written after the sediment concentration calculation has finished. Each line in the file contains first three indexes indicating for the node number. Then the total concentration is written and then lnumber floats that give the concentration for the sizes. An example is given below:

1 1 21 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00 0.000000e+00
1 2 2 5.075079e-04 0.000000e+00 1.026459e-04 1.030081e-04 1.032351e-04
1 2 3 4.064470e-04 0.000000e+00 1.011788e-04 1.015358e-04 1.017596e-04
1 2 4 4.004061e-04 0.000000e+00 9.967497e-05 1.000267e-04 1.002471e-04

If a file *conres.pre* exist, this will be read by the program before the sediment calculation starts. The *conres.pre* file has the same format as the *conres* file. Note only the sediment concentrations are given in the file, and not the grain size distribution of the bed. The concentrations are given in volume fractions.

The *con2res* file has the same information and format as the *conres* file, except that each line only starts with one integer before the concentrations are given. The integer is the cell number in the unstructured grid.

5.12 The *interpol* and *interres* files

Vertical profiles of velocity or concentration are sometimes needed. Coordinates for the locations where the profiles are wanted are given in this file. When the write results routine is activated and the integer on the *F 48* data set in the *control* file is above 1, it will search for this file. If this file is not found, it will proceed normally and write the result or the *conres* file. If the *interpol* file is found and the integer on the *F 48* data set is above 1, the program will not write to the result file, but write the interpolated vertical velocities to a file named *interres*. An example of an *interpol* file is given below:

M 2.03 0.5
M 4.06 0.39
M 4.06 0.5

The character *M* is read first, and then the *x* and *y* coordinates for the point one wishes to interpolate the vertical profile to. If the value on the *F 48* data set is 3 the concentrations are interpolated. If the value on the *F 48* data set is 2, the velocities, *k* and ε are written to the file. If the value on the *F 48* data set is 1, the bed levels are written (no profile, only one point). The results are written to a file called *interres*.

An example of an *interres* file is given below:

C 9.250000 0.100000, size = 0
1.530130 0.000000e+00
1.491877 5.266262e-05
1.415370 9.303652e-05
1.338864 1.349549e-04
1.262357 1.740915e-04
1.185851 2.075269e-04

The first line starts with a *C*, and then the *x* and *y* coordinates of the vertical profile is given. Two columns follow. The first column is the *z* value of the vertical profile. The second column is the concentration. If velocities are interpolated instead of concentrations, an *M* is written on the first line instead of the *C*. Instead of the concentration column, five columns are written. The variables in the columns are: velocity in *x*, *y* and *z* directions, *k* and ε.

Time-dependent sediment computations

If a time-dependent sediment computation is done, then the question is at what time should the concentrations be written? If the integer 19 is used on the *F 48* data set, then a time in seconds will be read first on each line of the *interpol* file. Also, a *T* is used as an index instead of an *M*. Example:

T 400.0 2.03 0.5
T 800.0 4.06 0.39
T 900.0 4.06 0.5

The *interres* file will then contain the sediment concentrations at this time.

The time in the file is given in seconds.

Printing cross-sections for ParaView from SSIIM 2.

Sometimes the user wants to see variables in a cross-section from a SSIIM2 grid. This can be done by specifying the integer 12 on the *F 48* data set, and print the "result" file. Then a ParaView file will be written from the cross-section defined in the *interpol* file. Only one cross-section can then be given in the *interpol* file.

5.13 The *verify* file

This file is used as input for the *VerifyProfile* graphics option. The user can present calculated velocity or concentration profiles together with measured values. Up to 20 vertical profiles in a section of the geometry can be shown. The horizontal location of the profiles are determined by the user, so this method of presentation can be used for both cross-sections, longitudinal section or other user-defined sections. An example of a *verify* file is shown below:

P 40.0 10.0 3
5.0 0.5 0.1
6.5 0.6 0.12
7.0 0.8 0.05
P 70.0 10.0 2
6.0 1.0 0.1
8.0 1.5 0.8

Each profile is identified with a capital *P*. Then the *x* and *y* coordinates of the point follow. The coordinates are given in the same system as the grid. After the coordinates, an integer is read. The integer tells how many points are measured in this profile. Up to 11 points can be given. On the following lines the data is given. There must be the same number of lines as the integer on the *P* line. Three floats are given on each line. The first is the vertical coordinate where the data is taken. This is given in the same coordinate system as the grid. The following two floats are velocities or concentrations, depending on what is calculated. If velocities are calculated, the second float is the velocity component in the x-direction and the third float is the velocity in the y- direction. If concentration is calculated, the second float is the measured concentration and the third float is a dummy number which is not used. If concentrations are given, the user can choose in the graphics presentation whether a total concentration or a fractional concentration is presented.

The example above gives two profiles. The first is located at x = 40.0 meters and y = 10.0 meters. Three data points have been measured. The first point is located at global coordinate z = 5.0 meters, and have a measured x-component velocity of 0.5 m/s and a y-component velocity of 0.1 m/s. The second point is located at global coordinate z = 6.5 meters, and have a measured x-component velocity of 0.6 m/s and a y-component velocity value of 0.12 m/s.

5.14 The *timei* and *timeo* files

There are two files that are relevant to time series calculations. The first file, *timei*, is an input file for time series of discharge, waterlevel, sediment concentration and control for output. The second file, *timeo*, is an output file with time series from the model.

There are several controls for the correctness of the data given in the *timei* file. If an error is detected by the program, a message will be written to the *boogie* file and the program will terminate.

The timei file can read different types of data sets, which all begins with a capital letter. The data sets beginning with *I* and *O* can be read in both SSIIM 1 and SSIIM 2.

The *O* data set

The *O* data set controls the output to the *timeo* file. A maximum of 20 *O* data sets can be used. The data set begins with a capital *O*, and then reads a float, *Time*, and an integer, *Vars*. *Time* is the time for when the print out starts, and *Vars* tells how many variables are written to the *timeo* file for each time step. Maximum 3000 variables can be written. After reading *Time* and *Vars*, the next lines read which

variables are printed and in which cell. *Vars* lines are read. Each line starts with a lower case character, and then three integers (four in case of sediment concentration) are read. This is for SSIIM 1. For SSIIM 2, only one integer is read (two for sediment concentrations). The integers indicate which cell the variable is located in. If sediment concentration is read (*c*), the last integer tells which fraction is written. 0 indicates the sum of the fractions. If water quality is read (*q*), another integer is also read, corresponding to which constituent is written. The characters corresponding to different variables are listed below:

character	variable
u	velocity in x-direction
v	velocity in y-direction
w	vertical velocity
p	pressure
k	turb. kin. energy
e	epsilon
d	turb. diffusion
z	vertical grid elevation
c	sediment concentration *
q	water quality component *

* These variables requires an extra integer read after the index(es) for the cell(s)

The *I* data set

The second type of data set is input data. The line starts with a capital I and then five floats are read. The first float indicates the time for when the following variables are used. The second float is the upstream water discharge. The third float is the downstream water discharge. The fourth float is the upstream water level, and the fifth float is the downstream water level. Sometimes one of the last variables are unknown, and then a negative value can be inserted and the program will try to calculate the value.

If the TFS method (*F 37 1*) is used in SSIIM 1, lnumber floats are read additionally, indicating the upstream inflowing sediment concentration (volume fraction).

If the TFS method is used in SSIIM 2, *N* x *lnumber* floats are read additionally. *N* is the number of inflow groups. The numbers indicate sediment concentration (volume fraction) of the inflowing sediments for each grain size. The sediment concentrations are grouped according to the inflow group. So that first, all the concentrations for the first group is given. Then the next group etc.

An example of a *timei* file for SSIIM 1 is given below:

O 0.0 6
u 2 2 2
c 2 2 2 0
p 2 2 2
z 41 3 6
z 1 2 1

z 2 2 1
I 0.0 10.0 10.0 -20.0 19.5.0 0.000
I 100.0 10.0 10.0 -20.0 19.0 0.000
I 200.0 10.0 10.0 -20.0 18.5 0.000
I 300.0 10.0 10.0 -20.0 18.0 0.000
I 400.0 10.0 10.0 -20.0 17.5 0.000

For SSIIM 2, the downstream water level on the I data set in the *timei* file corresponds to the first point in the *G 6* data set in the *control* file. If two fixed points are given in the *G 6* data set, the upstream water level on the *I* data set in the *timei* file will correspond. Note that this means the corresponding indexes on the G 6 data set and the I data set in the *timei* file are given in reverse order.

The *D* data set

For SSIIM 2, it is possible to have more than one inflow and one outflow group. Then it is also possible to vary the water discharge in each group over time. This is done using the additional *D* data set in the timei file. The data set gives the discharges for each time step, similar to the *I* data set. The first float read is the time. This must be identical to the time on the corresponding *I* data set. Then ten additional floats are read. The first nine are discharges in the nine first discharge groups. The last float is the water level. Note that zero's are given for the discharge groups that are not used.

If the water inflow is not equal to the outflow, there will be a water continuity error. To suppress the error message, and keep the program running, the *F 85* data set in the *control* file can be used.

An example of the *timei f*ile for SSIIM 2 is given below. There are three sediment sizes given in the *control* file. In the *unstruc* file, two inflow groups are given and one outflow group.

I 0 0.0 0.0 0.0 0.0 0.0 0.0012 0.0027 0.0 0.00029 0.00032
I 86400 0.0 0.0 0.0 0.0 0.0 0.0018 0.0021 0.0 0.00026 0.00038
I 172800 0.0 0.0 0.0 0.0 0.0 0.0011 0.0017 0.0 0.00027 0.00029
D 0 5.6 0.74 5.9 0.0 0.0 0.0 0.0 0.0 0.0 33.0
D 86400 5.4 0.54 15.1 0.0 0.0 0.0 0.0 0.0 0.0 33.0
D 172800 5.7 0.84 25.7 0.0 0.0 0.0 0.0 0.0 0.0 32.9

The time-varying discharge can also be used in the same way for water quality computations.

The *Q* data set

This data set only works for SSIIM 2. Ten floating point numbers are read. The first is the time step. The following nine are discharges in the nine discharge groups.

The *C* data set

This data set only works for SSIIM 2. A time step is first read. Then n times m floats are read, where m is the number of sediment sizes as given on the *G 1* data set, and n is the number of discharge groups where there is an inflow.

The *M* data set

The *M* data set us used to specify time-dependent inflow of water quality constituents for SSIIM 2. An *M* data set is also needed in the *control* file for each of the varying inflow concentrations. But instead of using the *I* or *J* data set in the *timei* file, an *M* data set is used. On this data set, the time is given first, similar to the *I* data set. Then a float is given, which is a variable time step. The variable time step is not coded yet, but it has but be given in the data set. Then the three floats for the wind is given, if wind is specified in the *control* file. Then up to 20 inflow concentrations are given. Note that the depth and water discharges from the *I* data set is not given. The number of inflow concentrations is the same as the number of *M* data sets in the *control* file. Irradiance read as the last number of the line, if specified by the *Q* data sets in the *control* file.

The order of the *M* data sets in the *control* file is not important, but the order of the data on the M data in the timei file has to be the same as the order of the *M* data sets in the *control* file.

The *timeo* file

The *timeo* file gives the output time series from the calculation. For each time step, a line of variables are written to the file. Each line has Vars floats, according to which variables were given in the timei file. In the above file six variables are written. The first variable is the velocity in x-direction for cell (2,2,2). The second variable is the sum of all sizes of concentration for cell (2,2,2). The pressure and vertical grid elevations for various grid intersections are written.

The second group of parameters in the *timei* file is an input time series. Each time step in the series are given on one line. The line starts with a capital *I*. Then the time step is given. Then four floats are read. This is the upstream and downstream water discharge and upstream and downstream water level, respectively. If a negative value is given, the program will try to calculate the value. The last float(s) are sediment concentration(s) for the various sediment sizes. These are only read if the transient sediment calculation is used. Note that the time steps does not have to correspond to the time steps of the program. The sum of the calculated time steps is calculated by the program and compared with the time step in the file. If the calculated time exceeds the time from the file, the values from this data line will be used. The times must be in increasing order.

An example of a *timeo* file corresponding to the above *timei* file (SSIIM 1) is given below:

0.0000e+00
2.0000e+00 8.804354e-01 6.837692e-04 -1.853305e+01 1.950000e+01 1.792479e+01
4.0000e+00 9.185002e-01 7.081983e-04 -3.949717e+01 1.950000e+01 1.792458e+01
6.0000e+00 1.100297e+00 1.121773e-03 5.289925e+01 1.950000e+01 1.792421e+01
8.0000e+00 1.156041e+00 1.389383e-03 8.122703e+01 1.950000e+01 1.792374e+01
1.0000e+01 1.207883e+00 1.614782e-03 9.418469e+01 1.950000e+01 1.792317e+01
...

Each line corresponds to a time step. A time step of 2 seconds have been used. The first float is the calculated time. The second float is the velocity in cell (2,2,2). Then the sum of the concentrations in cell (2,2,2) is written. Then the pressure and the vertical grid elevations.

This format is chosen so that it is easy to import the file into a spreadsheet for presentations.

5.15 The *forcelog* file (SSIIM 1 only)

This file contains time series of the forces on one or more obstacles for the transient free surface calculation. One line is written for each time step. An example of a forcelog file is shown below:

Forces on block 1 : 271.062, 0.099838 N in x and y direction
Forces on block 1 : 398.574, 0.082644 N in x and y direction

5.16 The *xcyc* and *koosurf* files

The two files *xcyc* and *koosurf* contain the geometry of the grid. This is used when restarting calculations which have changed the grid. The *xcyc* file is only used for SSIIM 1

The *koosurf* file is identical to the *koordina* file, except that the surface level is also written for each line. This is similar to using the *koordina* file with the tunnel option.

The *xcyc* file contains the *x*, *y* and *z* values of all the grid intersections.

When writing the files from the menu, both files will be written. When reading the files, SSIIM will try to read both files, but if the *xcyc* file is missing, it will only read the *koosurf* file. The internal grid nodes will be generated by linear interpolation, as given on the *G 3* data set in the *control* file.

If the internal nodes of the grid are generated by linear interpolation, the only necessary file is the *koosurf* file. However, for calculations where some part of the grid moves, and some is outblocked and does not move, it is necessary to save the *xcyc* file, and let SSIIM read this.

5.17 The *bedres* file (SSIIM 2 only)

The *bedres* file contains information about the bed sediments, including grain size distribution, thickness and bed form height. It also contains information about the bed roughness. This information is important when storing the results from a run that takes long computational times. The *bedres* file can then be read by SSIIM 2, to produce graphical results from the run, with regards to the sediments. When the *result* file is written from SSIIM 2, the *bedres.t* file is also written at the same time. If the user renames the file to *bedres* without an extension, then SSIIM 2 will search for this file before it reads the *result* file. It will then use the *bedres* file to update the grid so that it will be similar to the grid written to the *result* file. The result file will then be read into the grid it was produced by.

When using the P 10 option in the *control* file, multiple *bedres* files are written during a time-dependent run. These files can also be renamed to have no extension, and read by SSIIM together with the *result* file from the same time step.

The second line in the *bedres* file gives the structured grid size and the number of sediment sizes as the first four integers. This is the same integers as on the *G 1* data set in the *control* file. Then the number of 2D depth-averaged cells are written, and then the maximum depth. The maximum depth is used to determine the number of cells in the vertical direction, and is used in the same formula as the parameter on the *F 87* data set. The last number on the second line is an integer, giving how many cells there are in the grid.

Then there is a block of data where each line gives information about one depth-averaged cell. The first two integers on the line gives the i and j indexes of the cell in the 2D structured grid. The third number is a float. The integer value of this float gives the cell number of the bed cell in the 2D grid. Then four additional floating point numbers are given: the bed level, the water level, the limit of movable bed (from the *koomin* file) and the bed movement.

The last block of data gives information for each 2D depth-averaged cell in the grid. The 2D cell number is given first (which is not the same as the 3D cell number). Then the 3D cell number is given, then the roughness is given twice, the first time from a 3D array and the second time from a 2D array. Of course, these should be the same. Then the bedform height is given. After this, there will be 2(1+L) floating point numbers given, where *L* is the number of sediment sizes, as given on the *G 1* data set. First, the thickness of the active (top) bed layer is given in meters. Then the sediment fraction for each sediment size is given. Then the same is repeated for the inactive layer.

If multiple layers are used (*F 37 3* and *F 134*), then *N*(1+2L) floating point numbers are given, where *N* is the number of bed layers as given on the *F 134* data set.

The combination of reading the *bedres* and the *result* files have not always been successful. To avoid this problem, the *alldata* file can be used instead. It contains the grid, bed sediment information and the information in the *result* file.

5.18 The *habitat* file

The *habitat* file gives the availability function commonly used in analysis of fish habitat. The file is written at the same time as the *result* file. The availability function is divided in 20 groups, and tabulated so that it can easily be imported into a spreadsheet. This can be used to determine the preferences for the fish.

The file is written when the result file is written, if the *F 48* data set has the parameter 5.

5.19 Files for ParaView and Tecplot

SSIIM can generate graphic files that are read directly into the two programs ParaView and Tecplot. There are basically two version of the files: A 2D version and a 3D version. The files can be written from the user interface through the menu or from the main program. The main program can write multiple files for one time-dependent run, making it possible to create animations in the ParaView or Tecplot programs. The selection whether a 2D or a 3D file is generated can be specified on the *F 48* data set.

The files written by the main program (not by the SSIIM user interface menu) can write user-specified variables. The specification of the variables is given on the *G 24* data set. This data set reads a number of data groups, one group for each variable. Up to 30 groups/variables can be used. Each group consists of one character and two integers. The following table shows the details:

Variable	**Character**	**First integer**	**Second integer**
Horizontal velocity	*u or V*	Level	Not used
Vertical velocity	*w*	Level	Not used
Pressure	*p*	Level	Not used
Turbulent kinetic energy	*k*	Level	Not used
Epsilon	*e*	Level	Not used
Eddy-viscosity	*d*	Level	Not used
Sediment concentration	*c*	Level	Size number
Water quality	*q*	Level	Parameter number
Residual for horizontal velocity	*H*	Level	Not used
Residual for vertical velocity	*W*	Level	Not used
Residual for pressure	*R*	Level	Not used
Residual for turbulent kinetic energy	*K*	Level	Not used
Residual for epsilon	*E*	Level	Not used
Porosity or vegetation parameter	*P*	Level	Not used
Water level	*v*	Not used	Not used
Water depth	*y*	Not used	Not used
Froude number	*F*	Not used	Not used
Depth-averaged horizontal velocity	*D*	Not used	Not used
Number of cells in the vertical direction	*i*	Not used	Not used
Bed level	*z*	Not used	Not used
Bed shear stress	*m*	Not used	Not used
Roughness	*r*	Not used	Not used

Roughness to depth ratio	*h*	Not used	Not used
Bed form height	*b*	Not used	Not used
Sediment fraction	*f*	sediment layer no.	Not used
Sum of all sediment layer thicknesses	*l*	Not used	Not used
Sediment thickness of layer	*L*	sediment layer no.	Not used
Sediment thickness based on cell corners	*t*	Not used	Not used
Bed sediment d_{50}	*a*	Not used	Not used
Bed movement	*s*	Not used	Not used
Special temperature gradient	*x*	Not used	Not used
Bed angle	*B*	Not used	Not used
Secondary current angle	*C*	Not used	Not used
Potential bed sediment concentration	*O*	Not used	Not used
Groundwater level	*G*	Not used	Not used
Bed changes	*U*	Not used	Not used
Sediment slide movements	*M*	Not used	Not used
Bed solid fraction	*N*	sediment layer no.	Not used
Sediment cohesion	*j*	sediment layer no.	Not used

When printing Tecplot files from SSIIM 2, it is possible to use versions with both structured (2D) and unstructured (3D) grids. However, since SSIIM 2 uses an unstructured grid, printing the structured 2D Tecplot file, only the first block is written.

The *Paraview.vtk* file is a file similar to the *Tecplot.dat* file. The file can be viewed in the ParaView program, which is similar to Tecplot in functionality. ParaView is freeware and can be downloaded from the Internet.

In SSIIM 2, a three-dimensional ParaView file is written instead of a *result* file if the *F 48 10* is given in the *control* file. A more advanced option is to use the F 329 data set for making the ParaView files.

Making files with cross-sections for ParaView from SSIIM 2.

Sometimes the user wants to see variables in a cross-section from a SSIIM 2 grid. This can bed done by specifying the integer 12 on the *F 48* data set, and print the *result* file. Then a ParaView file will be written from the cross-section defined in the *interpol* file. Note only one cross-section can then be given in the file.

Both the Tecplot and Paraview programs may show strange results if using UTM coordinates with a large number of digits are used for the grid.

Making multiple files simultaneously

The *F 48* option in the *control* file has its limitations with respect to the choice of files that is written. A more flexible option is to use the *F 329* option. Then the user can chose to make (or not to make) fourteen different files for each print-out iteration given on the *P 10* data set.

5.20 The *fracres* file

The *fracres* file contains information about the thickness of the active and inactive layer and the grain size distribution in the two layers. Each line in the file describes one bed cell. The first two integers are the i and j values, identifying the cell in a structured grid. An indication about the index for each cell can be seen in the grid editor or the discharge editor, by choosing "View->legend" in the menu. This will give the index for the grid intersections. The corresponding cell will be in the direction of lower index values.

After the two integers, a floating point number is given, which is the thickness of the active sediment layer in meters. Then the fractions of each sediment size are given as floating point numbers. After that, the thickness of the inactive layer is given (meters). Then the fractions for the inactive layer are given. A total of 2 x (1 + n) floats are then read, where n is the number of sediment fractions.

Example: Three sediment sizes:

2 3 0.01 0.4 0.3 0.3 2.0 0.3 0.4 0.3

The line is for cell (2,3). The thickness of the active layer is 0.01 m. In the active layer there is 40 % sediments of size 1, 30 % of size 2 and 30 % of size 3. The inactive layer has a thickness of 2.0 meters, and contains 30 % of sediment size 1, 40 % of size 2 and 30 % of size 3.
The *fracres* file can be made by using a spreadsheet.

The *fracres* file is read by using an *O* (letter, not zero) on the *F 2* data set. Or reading the *compres/con2res* file from the menu. Also note that the active layer thickness in the *fracres* file must be the same as what is given on the *F 106* data set. If the *F 106* data set is not used, the active layer must be the same as the maximum grain size on the *S* data sets.

Note that the order of the bed cells in the *fracres* file is not important. Also note that the values for the same cell can be given multiple times. Then it is only the last value that will be used. This "feature" can be useful when regions of different sediments are to be described. Then the whole geometry can be covered in one particle distribution, and then the region of different distribution can be given afterwards. It is not necessary to remove the originally given values before adding new ones. This can be nested as many times as necessary. The only limitation is the length of the *fracres* file, which must have less lines than 20 x the number of bed cells. If this is a problem, it is easy to increase the number and recompile the program.

After the file is made, the user should read it and look at the grain size distribution and the sediment

thickness in the SSIIM graphics. Then possible mistakes can be seen.

5.21 The *bedangle* file (SSIIM 2 only)

The purpose of the bedangle file is to enable the user to give a spatially varying angle of repose for the sediments on the bed. The file is only used if an *F 274 1* data set in given in the *control* file.

The angles of repose are given on one line for each bed cell in the grid. Each line has two integers and four floating point numbers. The two integers identify the bed cell. Then four floating point numbers are read. The first two floating points are the angle of repose used to compute the reduction in the critical shear stress for erosion of a particle, for upstream slopes and downstream slopes. These values are typically used in the Brooks or Dey's formula. The values are given in degrees. Typical values are 25-50 degrees.

The third floating point number on the line is a lower limiter for reduction of critical shear stress. The reduction of the critical shear stress will not be below this value. The parameter should be between 0 and 1.

The first three parameters can also be given values on the *F 109* data set, for all the cells. Note that the angles given on the *F 109* data set is the inverse tangens to the angle, not the angle in degrees as given in the *bedangle* file.

The fourth parameter is the angle of repose used in the sand slide algorithm. This is also given in degrees. The variation in angle of repose for the sand slide algorithm is only coded for the *F 56 200* option.

Example:

3 4 40.0 35.0 0.2 33.0

5.22 The *inspace* file (SSIIM 2 only)

The inspace file enables the user to give a spatially varying inflow sediment concentration at the upstream boundary. The concentration is given as a function of the (*x,y,z*) coordinates of the center of the cell surfaces at the inflow boundary. The following function is used:

$$c = k_1 + k_2 x + k_3 y + k_4 h + k_5 x^2 + k_6 y^2 + k_7 h^2 + k_8 xy + k_9 xh + k_{10} yh \qquad (5.22.1)$$

The *x,y* and *z* coordinates use the same coordinate system as the grid. Instead of using the *z* coordinate, the *h* parameter is used, where *h* is the water depth, or the distance between the water surface to the center of the inflow surface, *z*. In other words: *h* = water level - *z*.

The values of the coefficients k_1-k_{10} are read on the *B* data sets or the *C* data sets in the inspace file. The *B* data sets are used if the concentrations do not change over time. The *C* data sets are used to specify time-variations of the parameters. For multiple grain sizes, one *B/C* data set is used for each size. An integer is read first, before the k_1-k_{10} values. The integer denotes the sediment size.

For time-variation of the parameters in Eq. 5.22.1, the number of time steps in the file must be given on the *F 294* data set in the *control* file. Also, *T* data sets must be given between each series of *C* data sets. The *T* data sets also contain a float, which is the time when the data set is used.

The *inspace* file starts with A 1.

Example: Two sediment sizes and two time steps:

A 1
T 0.0
C 1 0.0 0.0 0.0 0.0 0.0 0.0 0.001 0.001 0.0002 0.0002
C 1 0.0 0.0 0.0 0.0 0.0 0.0 0.002 0.001 0.0002 0.0002
T 3600.0
C 1 0.0 0.0 0.0 0.0 0.0 0.0 0.003 0.001 0.0002 0.0002
C 1 0.0 0.0 0.0 0.0 0.0 0.0 0.004 0.001 0.0002 0.0002

5.23 The *bagger* file (SSIIM 2 only)

The *bagger* file is used to specify a dredging operation. Bagger is the German word for dredging. The dredging function was first used in the Iffezheim reservoir, on the German-French border (Olsen and Hillebrand, 2018).

The dredging computations are invoked with the *F 386* data set in the *control* file. An integer is read, indicating how many dredging operations were done in the simulated time period. If the integer is larger than zero, then SSIIM will search for a file named *bagger* . The file describes the location, time and amount of the dredged material.

The *bagger* file has three types of data sets: *T, N* and *K*.

T: The *T* data set specifies the time period for the dredging. Two floats are read: the start and the end time of the dredgning. The times are in seconds, in the same reference as the times in the *timei* file. A maximum of 100 *T* data sets (dredging operations) can be used.

N: The *N* data set specifies which area of the grid is to be dredged. Four integers are read: i_1, i_2, j_1 and j_2. The integers are indexes for the (i,j) grid lines, as specified in the *koordina/koosurf/koomin* files. The lowest *i* index is denoted i_1, and the largest *i* index is i_2. The same for the *j* direction.

The *N* data set must follow directly after the *T* data set. There can be up to 20 *N* data sets for each *T* data set.

The *K* data sets contain the bed coordinates for grid line intersections at the end of the dredging period. The coordinate values are similar to what is given in the *koordina* file. For example:

K 3 5 34.4 124.3 8.4

The two integers give the grid line intersection indexes, while the following three floats give the *x,y* and *z* coordinates of the bed **right after** the dredging operation. Note that the *x*, *y* and *z* coordinates must be in the same reference system as the *unstruc/koordina* file. It is only the *z* coordinate that is used by the dredging algorithm.

The *K* data sets follows directly after the *N* data set. If there are more than one *N* data set for each *T* data set, then the following sequence is to be used:

T (first dredgning)
N (first area to be dredged)
K (first grid line intersection)
K
..
K (last grid line intersection)
N (second area to be dredged)
K (first grid line intersection in the second area)
K
..
K
T (second dredgning)
etc.

The volume of dredged material for each time step the dredging occurs is written to a file called *bag_res*. This is produced by SSIIM.

Generating the *K* data sets

A convenient method to generate the *K* data sets is from a point clout of measured bed elevations after the dredging operation. Often, such a point cloud have been measured to document how much material is removed from the bed. The measured coordinates can be transformed to a *geodata* file. Then this file is read into the *GridEditor* using the computational grid of the geometry. Then the bed is interpolated from the *geodata* points in the *GridEditor*, and the grid is regenerated. Then the unstruc file is written from the SSIIM menu. Simultaneously with writing the *unstruc* file, a koordina file is written. This will have the correct data for the K data sets in the bagger file. The koordina file is read into a spreadsheet, and the data for the dredged area is copied to another spreadsheet. Then the *K* is added in the first column, before the data from the *koordina* file. This is then save to an ASCII file and copied into the *bagger* file.

Remember to store the *unstruc* file first in another location, and copy it back to the working directory before the simulation is started.

5.24 The *alldata* file (SSIIM 2)

The *alldata* file is an attempt to combine the information from the *unstruc*, *result* and *bedres* files into one file. The idea was to be able to restart a morphological computation from one file.

The file can be written from the menu or by giving an *F 389* data set in the *control* file. The integer specifies how often the *alldata* file is written in a transient computation. If the integer is 1000, the *alldata* file is written each 1000th time step.

Chapter 6. Theoretical basis

6.1 Water flow calculation

The Navier-Stokes equations for turbulent flow in a general three-dimensional geometry are solved to obtain the water velocity. The k-ε model is used for calculating the turbulent shear stress. A simpler turbulence model can be used. This is specified on the *F 24* data set of the *control* file.

The equations are discretized with a control-volume approach. An implicit solver is used, also for the multi-block option. The SIMPLE method is the default method used for pressure- correction. The SIMPLEC method is invoked by the *K 9* data set in the *control* file. The power-law scheme or the second-order upwind scheme is used in the discretization of the convective terms. This is determined by the values on the *K 6* data set in the *control* file. The numerical methods are further described by Patankar (1980), Melaaen (1992) and Olsen (1991).

The Power-law scheme will reduce the diffusive flux as a function of the Pechlet number. This reduction is not used in the Second-order upwind scheme. It is also not used in the horizontal directions in SSIIM 2, only in the vertical direction. In SSIIM 1, the reduction is done in all directions.

The default algorithm in SSIIM neglects the transient term. To include this in the calculations the *F 33* data set in the *control* file is used. The time step and number of inner iterations are given on this data set. For transient calculations it is possible to give the water levels and discharges as input time series. The *timei* file is then used. For further description of this file, see Chapter 5.14.

The gravity term is not included in the standard algorithms. It is only invoked in some of the free-surface calculations, for modeling spillways and flood waves with steep fronts. The *F 36* data set is used to include the gravity term.

The wind shear stress, τ, on the lake surface is calculated as a function of the measured wind speed, using formula (4) in Olsen et al (2000).

The Boussinesq approximation

The eddy-viscosity concept is introduced with the Boussinesq approximation to model the Reynolds stress term:

$$-\overline{u_i u_j} = \nu_T \left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i} \right) \qquad (6.1.1)$$

The first term on the right side of the equation forms the diffusive term in the Navier- Stokes equation. The second term is often neglected, but can be included in SSIIM 1 by adding *F 100 1* in the *control* file.

The k-ε turbulence model

The k-ε model equations are given by Launder and Spalding (1974) . The equations for the k-w model is given by Wilcox (2000). The k-ω model can give less turbulent diffusion than the k-ε model, especially close to the walls.

In SSIIM, the wall laws for the k-ε model are used also for the k-ω model. This is due to the easier inclusion of wall roughness and the accuracy of the bed shear stress prediction.

Influence of density variations

The effect of the density variations on the water flow field is taken into account by introducing a modified eddy viscosity. The eddy viscosity from the k-ε model is multiplied with a factor taking into account the velocity and concentration gradients (Rodi, 1980):

$$\nu_T = \nu_T, 0 \left[1 + \beta \left(\frac{-g}{\rho} \frac{\frac{\partial \rho}{\partial z}}{\left(\frac{\partial U}{\partial z} \right)^2} \right) \right]^{\alpha} \qquad (6.1.2)$$

The eddy viscosity is denoted ν_T, b is a constant equal to 10, ρ is the density of the water/sediment mixture, U is the velocity, z is the geometrical distance in the vertical direction, g is the acceleration of gravity and a is a constant equal to -0.5.

Note that the same formula is used to change the turbulent diffusivity when calculating other parameters than the water velocity. The constants a and b then gets the values -1.5 and 3.33, respectively. The user can specify different parameters on the *F 82* data set in the *control* file.

Wall laws

The velocity gradient towards the wall is often very steep. If it is to be resolved in the grid, this will require too many grid cells. Instead, wall laws are used. This means that it is assumed that the velocity profile follows a certain empirical function, called a wall law. The equations we want to solve, both the Navier-Stokes equations and the turbulence equations, have certain discretized source terms in the main computational domain. For the cells close to the wall, where the wall laws are applied, the wall laws are used to derive analytical expressions for the source terms. These analytical expressions are used instead of the normal source terms. For example, when computing the velocities, the wall law is used to calculate the shear stress at the wall. The shear stress multiplied with the area of the cell side bordering the wall is used as a sink term in the velocity equation.

The default wall law in SSIIM is given below. It is an empirical formula for rough walls (Schlichting, 1979):

$$\frac{U(z)}{U_*} = \frac{1}{\kappa} \ln\left(\frac{30\, y}{k_s} \right) \qquad (6.1.3)$$

The shear velocity is denoted U_* and κ is a constant equal to 0.4. The distance to the wall is *y* and the roughness, k_s, is equivalent to a diameter of particles on the bed. It can be specified on the *F 16* data set in the *control* file. If the roughness varies at the bed, a roughness for each bed cell can be given in the *bedrough* file.

In SSIIM 1, it is also possible to use wall laws for smooth boundaries. This is done by giving an *F 15 5* data set in the *control* file.

Influence of sediment concentration on the water flow

Note that there is still a discussion about the following arguments in the science of sediment transport. Some of the theories below are not generally agreed upon.

The effect of the sediment concentration on the water flow can be divided in two physical processes:

1. The sediments close to the bed move by jumping up into the flow and settling again. This causes the water close to the bed to loose some of its velocity, because some of the energy is used for moving the sediments. This can be thought of as an added roughness. Einstein and Ning Chen (1955) conducted a set of classical experiments where they obtained a modified velocity distribution as a function of the sediment concentration. This function modifies the k constant in the law wall (Equation 6.1.17). The formula is:

$$\kappa = \kappa_0 \frac{1}{(1+2.5c)} \qquad (6.1.4)$$

This formula is hardcoded in SSIIM, and invoked automatically for the water flow calculation whenever the sediment concentration array has values above zero.

2. The other process is the sediment concentration increasing the density of the fluid, changing the flow characteristics. A typical example is a density current. This effect is added as an extra term in the Navier-Stokes equations:

$$\rho_s g \frac{\partial c}{\partial z} \qquad (6.1.19)$$

This term is not automatically invoked. The user can invoke this term by using the *F 18* data set in the *contro*l file.

Note that the two effects will move the velocity profile in opposite directions. Process 1 will decrease the water velocity close to the bed, while process 2 will increase the water velocity close to the bed.

6.2 Sediment transport

SSIIM calculates sediment transport by size fractions. In the *control* file, each fraction is specified on an *S* data set, where the diameter and fall velocity is given. This data set has to be given when calculating sediment transport. The number of sediment sizes is given on the *G 1* data set.

There are two methods to specify sediment inflow in the *control* file for SSIIM 1. One method is to give the inflow on the *I* data sets in kg/s. An *I* data set must then be given for each fraction. A vertical sediment concentration distribution according to the Hunter-Rouse Equation will then be used. This sediment concentration will be given over the entire upstream cross-section (*i*=1).

The other method to specify sediment inflow is to use the *G 5* data set. Then the concentration is given for a specified surface at the boundary of the grid. The concentration is given in volume fraction, which is used in all calculations by SSIIM. It is possible to use both *I* and *G 5* options simultaneously to specify multiple sources of sediments.

For SSIIM 2, the inflowing sediment concentration should be given in the *timei* file.

Specification of initial sediment fractions on the bed is done by using *N* and *B* data sets in the *control* file. The *N* data sets specify a number of sediment mixes. The distribution of the mixes in the various parts of the bed is given on the *B* data sets. In SSIIM 2, the initial spatial variation of the grain size distribution on the bed is given in the *fracres* file.

Theory

Sediment transport is traditionally divided in bedload and suspended load. The suspended load is calculated with the convection-diffusion equation for the sediment concentration, *c* (volume fraction in SSIIM):

$$\frac{\partial c}{\partial t}+U_j\frac{\partial c}{\partial x_j}+w\frac{\partial c}{\partial x_3}=\frac{\partial}{\partial x_j}(\Gamma\frac{\partial c}{\partial x_j})+S \qquad (6.2.1)$$

The fall velocity of the sediment particles is denoted w. The diffusion coefficient, Γ, is computed from the eddy-viscosity, ν_T, in the k-ε model:

$$\Gamma=\frac{\nu_T}{Sc} \qquad (6.2.2)$$

Sc is the Schmidt number, set to 1.0 as default. A different value can be given on the *F 12* data set in the *control* file.

S is a source term giving the pick-up rate of sediments due to erosion. The default formula is van Rijns (1984a) formula for suspended sediments. A number of other formulas can be used. This is chosen on the *F 84* data set. The empirical parameters van Rijns equation (0.015, 1.5 and 0.3) may be changed by using the *F 6* data set in the *control* file. Different sediment transport formulas can be coded in the *beddll.dll* file.

The procedure to take the sediment resuspension into account can be to specify a concentration in the bed cell, or use a pick-up rate as the source term in Eq. 6.3.1. The choice is specified on the *F 37* data set. *F 37 1* is using a specified concentration, and *F 37 2* is using a pick-up rate. The two options usually give very similar results.

The decrease in critical shear stress for the sediment particles as a function of the sloping can be bed can be taken into account by a number of formulas. They are given on the *F 182* data set. This process is particularly important when computing local scour (Bihs and Olsen, 2011)

Bed forms

The bed form height is calculated by van Rijns (1987) equation. The effective roughness is computed as (van Rijn, 1987):

$$k_s = 3\,d_{90} + 1.1\,\Delta\left(1 - e^{\frac{-25\,\Delta}{\tau_c}}\right) \qquad (6.2.3)$$

where l is the bedform length, calculated as $7.3d$.

Note that van Rjin's equations for bed form roughness was developed on mostly uniform sediments. For non-uniform sediments, the bed forms will be smaller.

A reduced effective shear stress for sediment transport due to shear stress partitioning can be invoked by using the *F 90* data set.

6.3 Temperature calculations

Temperature is calculated as a water quality component, by solving a convection-diffusion equation with a source term. Modeling temperature-stratified flow is only possible in SSIIM 2. Temperature must then be variable no. 0. The F *40 1.0* and *F 62 1* data sets must also be used in the *control* file.

Heat flux across the water surface

The heat flux across the water surface is calculated according to the following processes:

- solar short-wave radiation
- atmospheric longwave radiation
- longwave back radiation from the water
- conduction
- evaporation

The formula for the surface flux, I, can be written according to Chapra (1997):

(6.3.1)

In the formula, *Ir* is the irradiance, *T* is the temperature, s is the Stefan-Bolzman's constant, f(U_w) is a function of the wind speed, given by Chapra (1997) and e_s is the saturation vapour pressure at the water surface. The other parameters are given below in the description of the corresponding data set.

The parameters are specified on the *Q 1060* data set. Time series of wind speed, irradiance and air temperature are given in the *timei* file.

6.4 Water quality calculations

The water quality is calculated with a convection-diffusion equation for the concentration, *c*, of each water quality constituent. The difference from computing sediment concentration is the addition of extra source and sink terms, due to fluxes at the water surface and chemical and biological reactions. The source (sink=negative source) terms in the equations have been modelled in a number of different ways by various researchers and computer programs. A goal in the implementation of water quality in SSIIM was to give the user a flexibility on how to model each term. The user must therefore not only specify various reaction constants, but also specify each term in the source equation. This involves some more work than other models when making the input files, but it gives better flexibility for the user to make new terms and models for the various situations.

The user first have to decide how many constituents are to be simulated. The user have to number each variable from 0 to as many variables as is used. Presently, the maximum number of variables are 20. The number of variables have to be given on the *F 50* data set. The names of each variable is given in the *control* file on the *Q 0* data set. Note that only lower case letters have to be used, and a maximum of 40 characters. For each equation, the user have to specify the source terms in the equations. This is done on the *Q* data set in the *control* file. There are a number of various *Q* data sets, from *Q 1, Q 2 ...* etc. The various data sets are described in Chapter 5.3.9. Each data set gives a number of integers and floats. The first integer is always the index for the equation.

The temperature is defined as a water quality constituent. If the temperature influence on the water flow is to be modeled, as in stratified flow, the temperature has to be variable no. 0. Then also the data sets *F 40*, *F 62* and *F 67* may have to be used. This is only implemented for SSIIM 2.

Each source term in a convection-diffusion equation for a water quality parameter has its own *Q* data set. For example, if temperature, oxygen and nitrogen is simulated, this gives three variables. The following *Q 0* data sets can then be used:

Q 0 0 temperature
Q 0 1 oxygen
Q 0 2 nitrogen

The source terms then have to be specified. For simplicity, let us say that the temperature source is 0.1 times the oxygen concentration and the oxygen source is 0.3 times the temperature. The nitrogen source is 2.1 times the oxygen concentration multiplied with the temperature minus 0.4 times the

nitrogen concentration. This is then given as:

Q 1002 0 1.0 18.0
Q 1 2 1 0.3
Q 2 3 1 2 2.1
Q 1 3 2 -0.4

No more than 40 variables can be simulated, and it is not allowed to have more than 200 *Q* data sets in the *control* file.

The above example shows the flexibility of the program to incorporate new models for the various reactions. It also shows that the user is able to make models that make little sense from a biological/chemical point of view, and the program will allow this calculation to be carried out. The user must therefore have a good knowledge of water quality processes to give reasonable input data and to obtain reasonable results. Care must also be taken not to mistype numbers on the *Q* data sets.

Initial values

The initial values for water quality parameters when the calculation starts is given on the *G 41* data set. The data set specifies a vertical distribution of a variable. Horizontal homogeneity is then assumed for the initial values. For the temperature, it is also possible to use the *G 40* data set instead.

Inflow of water quality constituents for SSIIM 2

To have an inflow of nutrients or algae, the following is done:

In the discharge editor, a water discharge is given in different groups. Up to nine groups can be used. The water discharge and the group index is stored in the *unstruc* file.

The inflow concentration of nutrients is coded in the *control* file, on the *M* data set. The data set takes two integers and one float. The first integer is the same integer used to index the water discharge group in the unstruc file. The second integer is the number of the water quality constituent, similar to the *Q* data set. The float is the concentration of the nutrient. The data set can also be used to specify inflow of algae.

It is possible to specify a number of M data sets, according to the number of inflow groups and water quality constituents. If a nutrient has zero concentration at the inflow, it is not necessary to specify an M data set for it. It is not necessary to specify M data sets for the outflow.

Time-dependent variation in input parameters

To specify time-dependent inflow of nutrients, the timei file has to be used. Also, it is necessary to specify an *M* data set in the *control* file for each of the varying inflow concentrations. But instead of using the *I* or *J* data set in the *timei* file, an *M* data set is used. On this data set, the time is given first, similar to the *I* data set. Then a float is given, which is a variable time step. The variable time step is not coded yet, but it has but be given in the data set. Then the three floats for the wind is given, if wind is specified in the *control* file. Then up to 20 inflow concentrations are given. Note that the depth and

water discharges from the I data set is not given. The number of inflow concentrations is the same as the number of *M* data sets in the control file. Irradiance read as the last number of the line, if specified by the *Q* data sets in the control file.

Note that the order of the *M* data sets in the control file is not important, but the order of the data on the *M* data in the *timei* file has to be the same as the order of the *M* data sets in the *control* file.

Example:

control file:

..

Q 0 0 cyanobacteria
Q 0 1 phosphorous
Q 0 2 nitrogen
Q 0 3 algae_density
Q 0 4 light_history

fall velocity for algae:
algae_diameter form_resistance temperature
Q 131 0 3 0.0001 1.0 20.0

algae density:
a b c1 c2 c3 ks_irradiance min max
Q 282 3 0 4 0.0086 0.69 0.0022 0.00000028 0.0003833 25.0 0.7 1.3

light history:
a b averaging_period
Q 132 4 0 0.0086 0.69 86400.0

algae growth:
a b c1 c2 growth_phos+nit ks_phos ks_nit temp_const
Q 281 1 2 3 0.0086 0.69 1.18 1.0 0.82 0.0009 0.042 1.106

phosphorous depletion:
a b c1 c2 growth_phos+nit ks_phos ks_nit temp_const nutrient_fraction
Q 291 1 0 2 0.0086 0.69 1.18 1.0 0.82 0.0009 0.042 1.106 0.02

nitrogen depletion:
a b c1 c2 growth_phos+nit ks_nit ks_phos temp_const nutrient_fraction
Q 291 2 0 1 0.0086 0.69 1.18 1.0 0.82 0.0042 0.0009 1.106 0.14

q 42 0 0.0086 0.69 1.18 1.0 concentration, kc_(attenuation), c0, c1

M 1 0 0.001 inflow concentration of cyanobacteria
M 1 1 0.0003 inflow concentration of phosphorous

M 1 2 0.002 inflow concentration of nitrogen

timei file:

time timestep windspeed winddir_x winddir_y inflow0 inflow1 inflow2 irradiance

M 0.0 0.0 1.0 1.0 0.0 0.001 0.0003 0.002 0.0
M 1000.0 0.0 1.0 1.0 0.0 0.001 0.0003 0.002 10.0

Summary of special *Q* data sets:

The table below summarizes special *Q* data sets, including their creation date.

Q 1102: oxygen reaeration, 18/7-98
Q 1060: surface temperature flux, 17/7-98
Q 2030: resuspensjon, 17/7-98
Q 2149: SOD 30/7-98
Q 11: general fall velocity
Q 42: algae growth, Loch Leven, diatoms, 3/4-98
Q 113: time history of irradiance, 20/7-98
Q 120: WQRRS data set: algae
Q 121: predatation 17/7-98
Q 122: Pathogen, light, 20/7-98
Q 123: sorption fall velocity 17/7-98
Q 131: algae fall velocity, 20/6-98, const. temperature
Q 132: light history, set, 8/7-98
Q 133: light history, passive scalar, 10/7-98
Q 151: specific algae density, SCUM, one light att. coeff.
Q 152: algae growth, Leven, diatoms, 3/2-98
Q 161: specific algae density, SCUM, two param. light att., 30/6-98
Q 162: algae growth, Leven, diatoms, 3/2-98
Q 221: algae fall velocity, SCUM, 30/6-98, variable temperature
Q 230: WQRRS data set: algae
Q 252: algae growth, 20/7-98, multiple algae, one nutrient
Q 261: nutrient depletion 20/7-98
Q 272: diatom growth, 26/2-98, diatoms, silica, .
Q 281: algae growth, cyanobacteria, 25/6-98
Q 282: specific algae density, SCUM, 8/7-98, light history
Q 291: nutrient depletion, 25/6-98, one algae, two nutrients
Q 361: algae growth, cyanobacteria, 16/7-98, multiple algae, two nutrients
Q 371: nutrient depletion, 16/7-98, multiple algae, two nutrients

6.5 Modelling free-flowing algae

The special algal processes are only implemented in SSIIM 2.

Algae has two characteristics which needs special care in modelling. The first characteristic is its growth process. This is often both dependent on light and nutrients. The nutrients are often phosphorous, but nitrogen and silica may also be important for some species and situations.

The other main algae modelling characteristic is its fall/rise velocity. This is due to changes in its buoyancy. The buoyancy is often dependent on other parameters, for example irradiance.

A number of special data sets are made for different species of algae. Some of these can be used in combination with each other. Also, they can be used in combination with the other water quality data sets.

Two different groups of data sets are used, depending on whether there are multiple species of algae or only one single species contributing to the light shading. If there is only one species of algae, the light shading parameters are give in the growth data set. These types of data sets are described first.

Calculation of spatial distribution of algae includes modelling of the algal vertical rise/fall velocity. The rise/fall velocity is dependent on the algal density, algal diameter and a form factor. The algal density is dependent on the irradiance and the light extinction in the water body. Because the algal density depends on the values of the previous time step, it has to be modelled as a separate parameter. This means that modelling algae concentration necessitates an extra variable.

Some special *Q* data sets can be used to model algae settling and production. For example, *Q 151* is used to calculate the density as a function of the irradiance, *I,* light extinction coefficient, *k*, and a number of coefficients in the density formula. The time-dependent irradiance is given in the *timei* file. The amount of irradiance, *I*, decrease with the factor *f*, as a function of the water depth and the algae concentration. A formula for f is given by Olsen et al (2000), eq. 8. The computation of the change in the algae density is also described by Olsen et al (2000), together with the determination of the rise/fall velocity of the algae.

The *Q 42* data set models algal production. The computation of the algae growth rate is described by Olsen et al (2000), Eq. 10 and 11. The two last parameters on the *Q 42* data set are the a and b coefficients in Eq. 10 (Olsen et al, 2000).

Chapter 7. Programming SSIIM DLLs

7.1 Introduction

DLL is an abbreviation for Dynamic Link Library. Several functions of the SSIIM programs have been made into DLLs. This is linked into the main executable when SSIIM is started. The source code of the DLL is provided, giving the possibility to modify these functions, compiling them and using them in the main SSIIM program. This means access to a part of the source code for SSIIM.

When making SSIIM available on the Internet, it was intended that the program could be used and tested in the academic community, as MSc and PhD students would use it in their research. This has proven successful up to now. However, some students would also like to do some programming themselves as a part of their PhD research. Building a CFD model like SSIIM takes many years, and is beyond the scope of a PhD study. The new DLLs provides the possibility to program parts of SSIIM. The accompanying source code shows an example of this is done, and it is feasible for the PhD student to make changes to the code in relatively short time. By using the modified DLLs with SSIIM, researchers can test their own code without having to program other existing features of a CFD model, for example user interface graphics and other numerical algorithms.

The first DLL was made for the bed boundary condition for the sediment transport compuations. These algorithms are highly empirical, and considerable knowledge on sediment transport physics are required for their modification. Such knowledge is generated by basic sediment transport research, currently carried out by many universities in the world. Such research is essential to improving the predictional capabilities of the CFD programs.

7.2 Compilation

The Windows versions of SSIIM are made using the C++ compiler in the Microsoft Visual Studio 2005, together with the Intel compiler. The DLLs can be made using the same compilers. Free versions Microsoft compilers can be downloaded from Microsofts web pages.

In the following, it is described how the sediment bed functions DLL, beddll.dll, is made using the Microsoft Visual C++ 6.0 compiler. The same procedure is used for the other DLLs.

The beddll.zip file contains several source input files. Unzip the files into a separate subdirectory. Then start the compiler. Choose File -> Open, and in the dialog box choose All files *.* in the Files of type edit field. Then go to the directory where the beddll files are, and choose the file beddll.dsw. This loads all the files. In the left workspace window, choose FileView, and see all the Source Files. Then choose the beddll.cpp file. This file is then loaded in the main window. The file contains the six functions (A function in C is similar to a subroutine in FORTRAN). By scrolling in the window, the source code is seen, together with explanation of all the variables. The source code is written in C, and a basic

knowledge of this language is required.

After the file is modified, it should be saved, and then compiled. The compilation and making the beddll.dll file is done by using Build->Build beddll.dll. Possible error messages in the compilation have to be sorted out, and the process repeated. Finally, the beddll.dll file is made. This is located in the subdirectory Release or Debug, according to which of the two options is chosen (Debug is default). The beddll.dll file is then copied to the same directory as the SSIIM executable file and input files, and the SSIIM program can be run.

For further details, the user is referred to the documentation of Microsoft Visual C++.

7.3 The BEDDLL file - sediment transport functions

The sediment transport functions are given in the beddll.dll library. There are six functions:

- *computeShear*
- *computeCriticalShear*
- *computeBedSlopeCorrection*
- *computeBedConcentration*
- *computeBedForms*
- *computeBedRoughness*

The names indicate the purpose of the functions. A brief description is given below. More detailed information about the input parameters are given in the source code.

The *computeShear* function computes the shear stress on the bed as a function of the turbulent kinetic energy close to the bed. It is also possible to take into account the effect of the bed forms and the roughness as input parameters.

The *computeCriticalShear* function computes the critical shear stress for movement of a sediment particle. The default routine uses a parameterization of Shields graph, where the input parameters are the sediment size, density of the sediments and the bed shear stress.

The *computeBedSlopeCorrection* function computes the changes in the critical shear stress for the particle as a function of the sloping bed. The three vector components normal to the bed are used as input, together with the velocity vector components and two empirical parameters.

The *computeBedConcentration* is the main function for computing the boundary condition for the sediment transport. The default routine uses van Rijn's formulas, together with the Hunter-Rouse sediment distribution. A number of parameters are used as input, including the bed shear stress, critical bed shear stress, sediment size, empirical parameters, velocity components close to the bed etc.

The *computeBedForms* function computes the bed form height. Van Rijn's formula is used in the default routine. Input parameters are water depth, d50, d90 and a shear stress parameter.

The *computeBedRoughness* function computes the bed roughness. This is then used in the solution of the Navier-Stokes equation. Input parameters are bed form height, water depth, d90 etc.

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Appendix I. Transfer of grid between SSIIM 1 and SSIIM 2.

Transfer of grid from SSIIM 1 to SSIIM 2, alternative A.

1. Start the SSIIM 1 program with the existing grid.
2. Write the *XCYC* file from the menu. This also writes the koosurf file.
3. Make a new directory for the SSIIM 2 input files
4. Copy the SSIIM 1 *control* file to the new directory
5. Copy the *koosurf* file to the new directory
6. Copy the *koosurf* file to the file *koordina*
7. Edit the *control* file in the new directory. Increase the two first integers on the *G 1* data set by 3. . Save the *control* file
8. Start SSIIM 2.0 from the new directory
9. Start the *Grid Editor*
10. Choose from the menu: *Blocks->Add block from koosurf*
11. Generate the grid (Menu option: *Generate -> 3D Grid*)
12. If an allocation error occurs, increase the numbers on the *F 65* data set in the *control* file and start from point 8 again.
13. Write the *unstruc* file
14. End the program
15. Check the *boogie* file to see if an allocation error has occurred. If so, increase the numbers on the *F 65* data set in the *control* file and start from point 8 again.
16. Start SSIIM 2.0 again
17. Enter the *Discharge Editor*
18. Specify the discharge
19. Write the *unstruc* file.
20. If you want to start the computations with a grid with a lower water surface, then edit the *koordina* file so that it contains the new water surface. Then add the *F 112 1* data set to the *control* file. The program then removes dry cells in the startup procedure.

Transfer of grid from SSIIM 1 to SSIIM 2, alternative B.

The *koosurf* file in SSIIM 1 is similar to the *koordina* file in SSIIM 2. Follow the instructions below:

1. Start the SSIIM 1 program with the existing grid.
2. Write the *XCYC* file from the menu. This also writes the *koosurf* file.
3. Make a new directory for the SSIIM 2 input files
4. Copy the SSIIM 1 *control* file to the new directory
5. Copy the *koosurf* file to the new directory
6. In the new directory, rename the *koosurf* file to *koordina*
7. Edit the *control* file in the new directory, and note the two first numbers on the *G 1* data set, *i* and *j*, on a separete piece of paper.
8. Increase *i* and *j* by 3 and save the *control* file
9. Start SSIIM 2.0 from the new directory
10. Start the *Grid Editor*

11. Make one block anywhere in the window. The size of the block given in the dialog box must equal to the **original** *i* and *j* from point 7.
12. Use the Transfinite Interpolation if the grid looks strange (Menu option: *Generate -> TransfiniteI*)
13. Generate the grid (Menu option: *Generate -> 3D Grid*)
14. If an allocation error occurs, increase the cell numbers on the *F 65* data set in the *control* file and start from point 9 again.
15. Write the *unstruc* file
16. End the program
17. Check the *boogie* file to see if an allocation error has occurred. If so, increase the cell numbers on the *F 65* data set in the *control* file and start from point 9 again.
18. Add an *F 94* data set to the *control* file, giving the minimum cell height. If this is too small, instabilities will occur. The default is very small.
20. Start SSIIM 2.0 again
21. Read the *unstruc* file
22. Enter the *Grid Editor* (Note that the window may be blank. Just proceed with next point)
23. Generate the 3D grid (Menu options: *Generate -> 3D Grid*)
24. Write the *unstruc* file.
25. Start SSIIM 2.0 again
26. Enter the *Discharge Editor*
27. Specify the discharge
28. Write the *unstruc* file.
29. If you want to start the computations with a grid with a lower water surface, then edit the *koordina* file, so that it contains the new water surface, and add the *F 112 1* data set in the *control* file. The program then removes dry cells in the startup procedure.

Transfer of grid from SSIIM 2 to SSIIM 1.

Transfer of grid from SSIIM 2 to SSIIM 1 is only possible if the grid has one block.

1. When the *unstruc* file is written from SSIIM 2, a file called *koordina.si1* is written at the same time. This file can be used by SSIIM 1. Copy the file to a separate directory, and rename it *koordina*, without an extension.

2. Copy the *control* file to the same directory.

3. Edit the *G 1* data set in the *control* file so that the grid size is the same as the block generated in SSIIM 2.

4. Remove SSIIM 2 - specific data sets from the *control* file.

The default algorithm in SSIIM 1 defines one side to be inflow and the other outflow. To make the SSIIM 2 grid compatible with this definition, the *GridEditor* in SSIIM 2 has the menu option *View->SSIIM 1 inflow/outflow*. This shows with a text what is inflow and outflow. The grid can be rotated with the menu option *Blocks->Rotate+/-* to get the inflow and outflow at the correct side.