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MODELING AT VASISHTA GODAVARI RIVER MOUTH USING FESWMS - 2DH

आपो हि ष्ठा मयोभुव

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ABSTRACT

The surface water levels of a river, especially at mouth, are required for planning and managing flood alleviation schemes and river engineering works. In the lower reaches of many rivers, flood plain inundation may result from a very high tide or a very high flood or a combination of both. Also, the extent of landward intrusion of saline water into a river at, mouth, varies with the relative strength of fresh water discharge and the co-oscillating tidal flow resulting from the dynamical interaction of the adjacent coastal waters.

An attempt is made to simulate the flow process over a reach of 10 km in the Vasishta river mouth in the Godavari delta. A finite element surface water modelling system, FESWMS developed by USGS is implemented to model the reach. Since the Godavari at mouth is wide and shallow ,it is expected that the model may simulate the flows reasonably well. Unlike in an estuary hydrodynamics may not be so dominant at the Godavari mouth as it drains an area more than half of deccan plataeu.

The outcome of this two dimensional depth averaged flow modelling study is to simulate the water level and velocity distribution in the study reach for different tide conditions during the flood scenario during which there is lot of variation in river flows.

1.0 INTRODUCTION

The surface water levels of a river, especially at mouth, are required for planning and managing flood alleviation schemes and river engineering works. In the lower reaches of many rivers, flood plain inundation may result from a very high tide or a very high flood or a combination of both. Also, the extent of landward intrusion of saline water into a river at, mouth, varies with the relative strength of fresh water discharge and the co-oscillating tidal flow resulting from the dynamical interaction of the adjacent coastal waters.

In many surface water flow problems of practical engineering concern, three dimensional nature of the flow is of secondary importance, particularly when width to depth ratios are large. In such a case the horizontal distribution of flow may be the main interest and two dimensional flow approximations can be used to great economic advantage. Also the present state of the art and lack of suitable data in most cases may not justify more complex three dimensional solutions to many a surface water flow problems, especially at shallow rivers, flood plains, harbours, coastal areas and estuaries, where flows are essentially two dimensional.

FESWMS-2DH is a modular set of computer programs developed to simulate surface water flow where essentially the flow is two dimensional in horizontal plane. The program was developed by USGS and is written in the FORTRAN-77 language.

The modeling system can be used to simulate flow in water bodies that have irregular topography and geometrical features, such as islands and highway embankment. Flow over dams, weirs and highway embankments and through bridges, culverts and gated openings also can be modeled.

FESWMS-2DH calculates the depth averaged horizontal velocities and water depths and the time derivatives of these quantities if a time dependent flow is modeled. The equations that govern depth averaged surface water flow account for the effects of bed friction wind induced stress at the water surface, fluid stress caused by turbulence and the effect of the earth's rotation. Because velocity in the vertical direction is not modeled, evaluation of phenomena such as stratified flow is beyond the scope of the modeling system. Also, because water density is assumed constant, flow resulting from horizontal density gradients can not be evaluated. By modifying the input data that describe an existing physical system, the effect of changes to the system can be forecast.

An attempt is made in this study to simulate the surface water levels and velocity distribution in the lower 10 km reach of Vasishta river mouth area in the Godavari delta, using the two dimensional depth averaged FESWMS. The study is conducted over a tidal period during the flood season.

2.0 REVIEW:

The rhythmic nature of tides i.e., alternating rise and fall in sea level relative to land surface is produced by a combination of forces namely the force of gravitational attraction of the moon and the sun on earth, the centrifugal force produced by the revolution of earth-moon system about their common centre of mass , the centrifugal force produced by the revolution of the earth around the centre of mass of the earth-sun system and the rotation of the earth about its own axis. In the coastal and nearshore environment tides and waves operate together to produce a complicated geomorphology, especially at the river mouths through which lot of water from the earth's surface is discharged. Complicated tidal currents can generate dangerous sand heads in shipping channels. Pressure systems forming at sea surface may disturb the regular tidal pattern resulting in surges having a periodicity of a few minutes to several hours. The increase in sea level in the from of surge can give rise to serious coastal flooding especially when it occurs during high water level during spring tide (Joseph,1997). The situation may be worse at the river mouth when surge occurs during the flood time. Such a situation may result in extensive damage to structures along or near the coast, submergence of islands, damages to fertile land by making them saline, contamination of fresh groundwater resources, and sand casting of fields.

The theory of tides was given sound mathematical shape by the British Physicist, Sir Issac Newton, Swiss mathematician David Bernoulli, French astronomer and mathematician Marques de Laplace and the British Physicist Lord Kelvin. Attempts have been made at different times towards a mathematical method of approach to the mechanism of tidal motion where from solution can be obtained for the tidal conditions throughout the river system. Attempts at mathematical treatment by indirect means have been made by a number of mathematicians, physicists and engineers in different parts of the world.

The unique physiographic features of tidal inlets make it convenient to treat inlet hydraulics into two parts, one pertaining to the channel through the land barrier and the other to the near field region characterized by ebb and flood circulation beyond the channel.

Inlets have attracted the attention of hydraulic engineers (Brown 1928; Brunn and Gerritsen 1960; Chapman 1923; Eads 1971; Escoffier 1940; Keulegan 1967; O'Brien 1931; Stevenson 1886; Watt 1905). Hydraulic information of interest includes temporal and spatial variations of currents and water levels in the channel and vicinity. Depending upon the degree of accuracy of the answer desired several predictive approaches are available. Mehta and Joshi (1988) depict the outcome of reports of ASCE task committee in tidal inlet hydraulics. Channel and near field hydraulics are described in the sequel with reference to analytic solutions followed by the physical and numerical modeling. Relatively simple analytical approaches , even though approximate, yield quick answers and are used extensively.

Webster and Wardlaw (1993) illustrated the steps involved in the analytical approach and described its application to drainage basins in Hong Kong, in which water level in tidal streams are subject to the influence of both fluvial and tidal factors. The interaction between such factors is rendered more complex in regions affected by typhoons, which typically result in the combined occurrence of heavy rainfall and high sea levels. Previous studies have outlined an analytical approach for calculating design water levels based on dividing the fluvial and tidal series into a typhoon and non-typhoon components. The suggested approach provides a practical means of calculating design water levels and is recommended for final design purpose. This problem can also be called as typhoon estuary problem.

Acreman (1994) developed a solution for risk assessment in the lower river Roding by reconstructing of the historical water levels from river flow and tidal records using a hydraulic model. Water levels in the lower reaches of most rivers are controlled by the interaction of fluvial flows and tides. Assessment of the risk of overbank inundation, therefore, requires an estimation of the probability of experiencing combination of river floods and high tides and calculation of water levels resulting from their interaction. This has been achieved by numerical integration of the marginal probability distribution of river floods and sea levels, but this is complex mathematically and requires explicit knowledge of the correlation structure. The model allows for operation of the river Rodings flood protection barrier and for the effects of a general rise in sea level.

Dube et.al (1994) described a real time storm surge prediction system which has been applied to the east coast of India. The east coast of India is threatened by the possibility of storm surge floods whenever a tropical cyclone approaches and results in damage to coastal structures and property. The storm surge prediction system is based on the numerical model developed earlier for the region. Surface winds associated with a tropical cyclone are derived from a storm model developed by Jelesniaski and Taylor(1973), which requires the position of the storm, the pressure drop and the radii of maximum winds. The model has been used to simulate the surge generated by severe tropical cyclones during the last three decades and the computed surge is found to be in good agreement with the available observations. The limitation of this model is that it assumes the coast line as a vertical wall and depends on the detailing of the bed morphological characteristics of the coasts and river mouths.

Ramana et.al (1989) studied the distribution of salinity and currents in Vasishta branch of Godavari esturine system at three stations with respect to fresh water discharges in the river during July, September and February. During flood season i.e., July the stations situated in the interior did not appear in the stratification circulation diagram as the stream is filled with fresh water at all levels. In February i.e., lean flow season all the three stations represented well mixed flow conditions.

Rao, et.al (1994) applied multi-level numerical model to simulate the flow and salinity structure in the Vasista branch of the Godavari at its mouth. Conditions in the estuary are characterized by a seasonally varying fresh water discharge and saline water intrusion from the Bay of Bengal due to the currents associated with semi-diurnal tide. The model resulted in understanding the circulation pattern at the mouth.

Chandra Mohan (1993) presented the application of FESWMS-2DH, to estuarine hydrodynamics and illustrated the importance of the model in simulating water levels and velocity distribution under different climatic conditions.

3.0 STUDY AREA:

A reach of 10 Km from the mouth of Vasishta branch of the Godavari river in the delta portion is considered for simulation using FESWMS-2DH (Fig.1) Based on the topographical and bathymetric information (Ramana et.al, 1989) the reach is approximated as an area with a breadth varying from 750 m to 900 m and depth varying 12.5 m to 15 m from u/s to d/s. A discharge of 235000 cusecs or 6654.46 cumecs is considered at river end and semi-diurnal tidal conditions at mouth is imposed. A cross bed slope of 1 in 100 is assumed due to non availability of detailed bathymetric information.

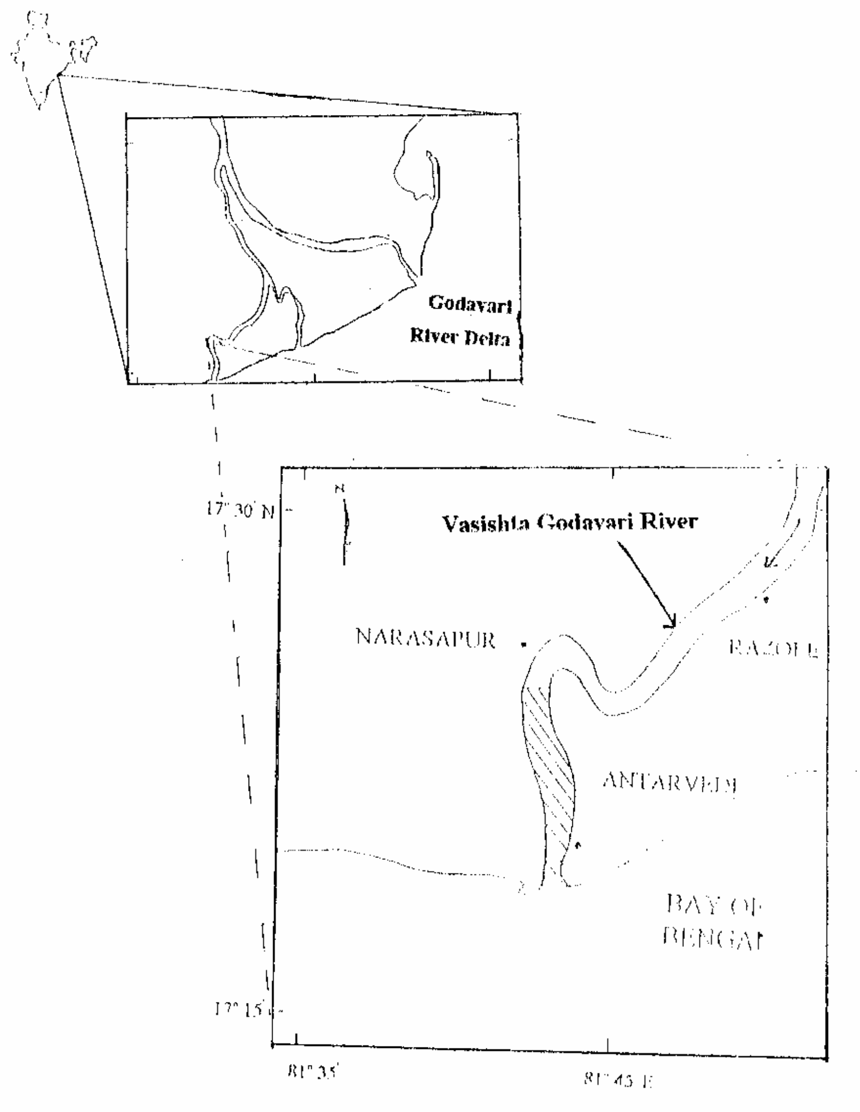

Fig.1 Study Area

A finite element network is formulated (fig.2) to approximate the true representation of the reach. The entire reach is considered to have uniform properties. 25 elements having 121 nodes are used to identify the reach. The bed level contour map, as considered, is shown in fig.3.

4.0 MODEL DESCRIPTION:

FESWMS-2DH uses the Galerkin's finite element method to solve the governing system of equations for two dimensional flow in a horizontal plane. Galerkin's method of weighted residuals , a Newton-Raphson iteration scheme, numerical integration using seven point Gaussian quadrature, and a frontal solution algorithm using out -of-core storage are used to solve for the nodal values of the velocity components and depths. Time derivatives are handled by an implicit finite difference scheme.

Governing Equations :

Neglecting vertical velocities and vertical accelerations, the depth averaged velocity may be obtained by integrating the horizontal velocity components from the bed elevation to the water surface. An illustration of the depth averaged velocity is shown in fig.4

The depth averaged velocity along the X-axis is given by,

$$U = 1/H \int_{z}^{z+h} u\,dz \qquad \text{------------- (1)}$$

and the depth averaged velocity along the Y-axis is given by,

$$V = 1/H \int_{z}^{z+h} v\,dz \qquad \text{------------- (2)}$$

The two dimensional depth averaged equations of motion used in FESWMS-2DH to describe the movement of water are :

the conservation of mass,

$$\partial H/\partial t + \partial(H.U)/\partial x + \partial(HV)/\partial y = \phi \qquad \text{----------------(3)}$$

the conservation of momentum in X direction,

$$\partial(H.U)/\partial t + \partial(\beta\, uu\, HUU)/\partial x + \partial(\beta\, uvHUV)/\partial y + gH\,\partial Zb/\partial x + 1/2\, g\,\partial(HH)/\partial x - \Omega\, HV + 1/\rho\, [\,\tau^{b}{}_{x} - \tau^{s}{}_{x} - \partial(H\tau_{xx})/\partial x - \partial(H\tau_{xy})/\partial y] = \phi \qquad \text{---------------- (4)}$$

and the conservation of momentum in Y direction,

$$\partial(H.V)/\partial t + \partial(\beta\, vu\, HVU)/\partial x + \partial(\beta\, vvHVV)/\partial y + gH\,\partial Zb/\partial y + 1/2\, g\,\partial(HH)/\partial y - \Omega\, HU + 1/\rho\, [\,\tau^{b}{}_{y} - \tau^{s}{}_{y} - \partial(H\tau_{yx})/\partial x - \partial(H\tau_{yy})/\partial y] = \phi \qquad \text{------------------- (5)}$$

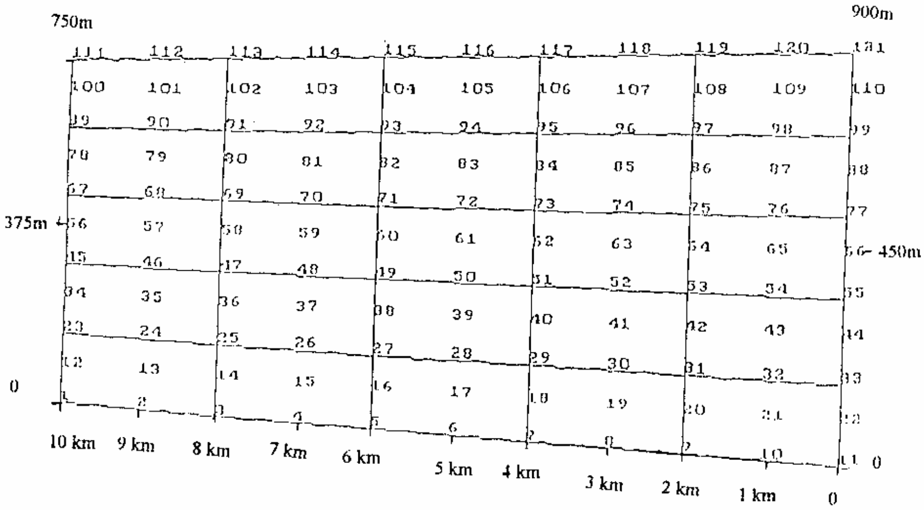

Fig.2 Finite Element Network

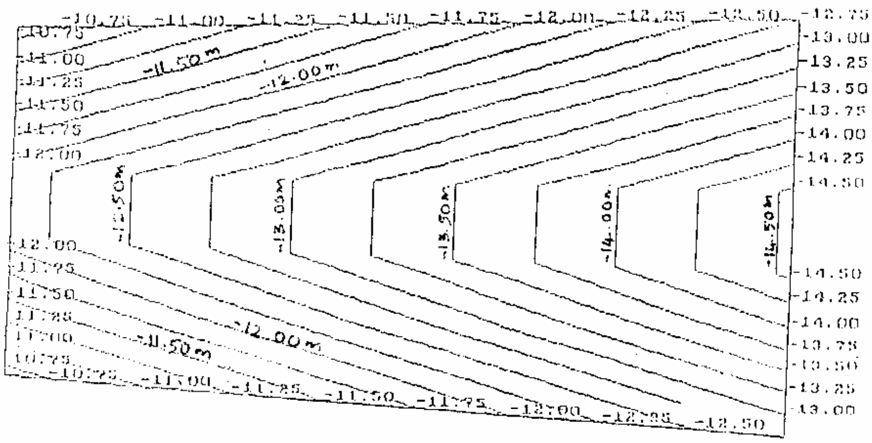

Fig.3 Bed Level Contour Map

where, β 's are momentum correction coefficients that account for the variation of velocity in vertical direction; g is gravitational acceleration; Ω is coriollis parameter; ρ is the density of water which is assumed as constant; τ_x^b, τ_y^b are bottom shear stresses and τ_x^s , τ_y^s are surface shear stresses acting in the x and y directions respectively; and τ_{xx} , τ_{xy} , τ_{yx} , τ_{yy} are shear stresses caused by turbulence where for example τ_{xy} is the shear stress acting in the x direction on a plane that is perpendicular to the y direction. Other variables are as specified in Fig. 4.

In the conservation of momentum equation, the first three terms describe the inertial force. The fourth and fifth terms describe the pressure gradient resulting from a sloping water surface. The sixth term represents the Coriolis force which acts perpendicular to the velocity. The seventh and eighth terms represent bottom stresses and surface stresses respectively. The ninth and tenth terms represent the effects of the Reynolds stresses. Boussinesque eddy viscosity concept is used where the momentum transfer is proportional to the mean velocity gradients.

The stretch attempted to be modelled using FESWMS-2DH is a wide and shallow one as the depths are only about 12.5 to 15.0m and the widths are varying from 750 to 900m. Hence the assumption that velocities are considered uniform in the study may be an acceptable one, though the reach is tidally effected. Also FESWMS-2DH is developed to model the water surface of areas having similar features.

FESWMS-2DH uses the Galerkin's finite element method to solve the governing system of differential equations. The solution begins by dividing the physical region of interest into a number of sub regions, which are called elements. An element can either be triangular or quadrangular in shape and is defined by a finite number of node points situated along its boundary or in its interior. A list of nodes connected to each element is easily recorded for identification and use. Values of dependent variables are approximated within each element using values defined at the element's node points, and a set of interpolation (or shape) functions. Mixed interpolation is used in FESWMS-2DH; quadratic interpolation functions are used to interpolate depth averaged velocities and linear functions are used to interpolate flow depth.

The method of weighted residuals is applied to the governing differential equations next, to form a set of equations for each element. Approximations of the dependent variables are substituted into the governing equations, which generally are not satisfied exactly, to form residuals. The residuals are required to vanish, in an average sense, when they are multiplied by a weighting function and summed at every point in the solution domain. In Galerkin's method, the weighted functions are chosen to be the same as the interpolation functions. By requiring the summation of the weighted residuals to equal zero, the finite element equations take on an integral form. Coefficients of the equations are integrated numerically, and all the element (local) equations are assembled to obtain the complete (global) system of equations. The global set of equations is solved simultaneously.

Initial and Boundary Conditions :

To solve the system of depth averaged flow equations, both initial and boundary conditions need to be specified. From the mathematical point of view, the initial condition and the number and kind of boundary conditions that are specified need to make the problem well-posed (stable). A well-posed problem is one in which increasingly smaller changes to boundary conditions produce increasingly smaller changes in the solutions at points not located on the boundary. The system of equations that exhibits unstable behavior is said to be ill-posed.

Initial conditions :

To obtain a solution, both the water depth and the depth averaged X and Y velocity components need to be specified as initial conditions throughout the entire solution region. When initial conditions are unknown, a cold start procedure is used. During this procedure, the same water surface elevation is assigned to every node point in a finite element network, and velocities are set to zero everywhere. With the results from a previous run are available, they can be used as initial conditions for a subsequent run. The use of results from a previous run as initial condition is referred to as a hot start.

Boundary Conditions :

Boundary conditions are specified around the entire boundary of a network for the duration of a simulation. The required boundary information depends on the type of boundary, solid or open and the flow condition, sub critical or super critical.

a) Solid Boundary - The flow across a solid boundary generally equals zero. In addition, either the tangential velocity or tangential stress needs to be specified on a solid boundary. Along solid boundaries, either tangential stresses are assumed to equal zero (a slip condition) or the velocity is set to zero (no slip condition).

b) Open Boundary - An open boundary defines an area where flow is allowed to enter (an inflow boundary) or leave (an outflow boundary) a finite element network.

Usually unit flow in both X and Y directions may be specified at inflow boundary nodes , and water surface elevation may be specified at outflow boundary nodes of a model.

Modeling System :

FESWMS-2DH consists of three distinct but related programs : DINMOD, the data input module; FLOMOD, the depth averaged flow analysis module; and ANMOD, the output analysis module.

As a preprocessing program, DINMOD checks the input data for errors, generate plots of the finite element network and ground surface contours, and puts the network data in an appropriate form for subsequent analysis. The solution of the 2-D depth averaged flow equations are performed by FLOMOD. The postprocessing program, ANOMOD, generates plots and printed reports from the network data and the flow data.

DINMOD :

The primary purpose of DINMOD is to generate a two dimensional finite element network (grid). Functions performed by this program include editing of input data, automatic generation of all or part of the finite element network, refinement of an existing network, ordering of elements to enable an efficient equation solution, and graphic display of the finite element network. As such DINMOD acts as a preprocessor of the finite element network data. Processed network data can be stored in a data file for use by other FESWMS-2DH programs.

FLOMOD :

FLOMOD simulates both steady and unsteady (time-dependent) two dimensional surface water flow. The program numerically solves the vertically integrated equation of motion and continuity, using the finite element method of analysis, to obtain depth averaged velocities and flow depths. The effect of bed friction and turbulent stresses are considered , as are optionally, surface wind stresses and coriolis force. The computed two dimensional data can be written to a data file and stored for further use.

ANOMOD :

Results of flow simulations are presented graphically and in the form of reports by ANOMOD. Plots of velocity and unit flow vectors, ground surface and water surface elevation contours and time history graphs of velocity, unit flow, or stage (water surface elevation) at a particular computation point can be produced. As such, ANOMOD acts as a postprocessor in the modeling.

Network design:

The basic goal of network is to create a representation of the water body, that provides an adequate approximation of the true solution of the governing equations, at a reasonable cost. FESWMS-2DH will accept any combination of 6 node triangular, 8 node quadrangular or 9 node quadrangular elements that have straight or curved sides so that complex geometries can be modeled in detail. Curve sided elements can be created by specifying the coordinates of the mid side node as well as the corner nodes of sides that are curved.

Data Requirements :

Data requirement for FESWMS-2DH can be classified as topographic, network and hydraulic data.

Topographic Data :

a) Contour map of the area to be modeled, at a reasonably close interval.

b) Types of soils, vegetation and topography at different locations of the study area which can be used to estimate fairly accurately, the values of roughness coefficients at these locations.

Network Data

Once the study area is broken into a finite element network which consists of nodes and elements, it is required to know X and Y coordinates with respect to an origin and ground surface and/or ceiling elevation at each node point of an element. Node connectivity list has to be prepared for each element, which means listing of nodes, by which an element can be defined, in a counter clockwise direction.

Hydraulic Data :

a) Model parameter values such as Manning's roughness coefficient and kinematic eddy viscosity for each element

b) Upstream and downstream boundary conditions such as discharges and water surface elevations

(tidal cycle in the case of tidally effected area)

c) Initial conditions (X velocity, Y velocity and water surface elevations) at each node.

d) Wind speed and direction at each node points.

Model Parameters

The important model parameters are roughness coefficients and kinematic eddy viscosity. Once the sensitivity of the model and its outputs to the changes in these parameters are clearly understood, the model can be used effectively.

5.0 DATA:

The details of data used for modeling are as below

DINMOD Data:

Model topography is described by giving the ground surface depths or elevations at each node point and letting it to vary linearly within an element. Location of each element is fixed by (a) input, X and Y coordinates for corner nodes and (b) by providing node connectivity list for each element i.e., inputting the list of nodes by which an element can be defined in anticlockwise direction. Flow properties of the each type of elements are separately given in FLOMOD data file.

FLOMOD Data :

Inflows from the upstream of river into the study reach is to provide an upstream boundary condition. Peak flow of 235000 cusecs(6654.46 cumecs) was applied at this end. Down stream boundary conditions were provided at the mouth end by specifying an average tidal cycle. Since the entire reach is treated as uniform one from hydraulic characteristics point of view a mannings value is assumed.

Cold Start :

Since the initial conditions, values of X and Y velocities and water surface elevations at each node point are not known, a cold start procedure is to be followed to get an approximate initial condition values. For a cold start run, X and Y velocities at all node points were kept to zero and water surface elevations at each node points were assumed to be 0.001 m above mean sea level (msl). At this point of analysis, velocity gradients will be very large and the convergence to a solution becomes difficult. To overcome this a temporary high value of kinematic eddy viscosity of 92.92 sq.m/s (1000 sq.ft/s) was assumed for the first run which will encourage solution convergence within a few iterations, because of the dampening effect of high viscosity.

Hot Start :

Values of dependent variables u,v and water surface elevations from previous cold start run have been taken as initial condition for the next hot start run. Magnitude of eddy viscosity has been gradually reduced to 0.930 sq.m/s (10 sq.ft/s) which is a physically possible value.

ANOMOD Data :

ANOMOD gives pointwise outputs for time history report of velocity, unit flow and stage. ANOMOD plots time history graphs for velocity, unit flow and stage at node points. It also gives velocity vector plots and velocity and water surface contour plots for the whole study area.

As an initial step in the application of this model, flow was taken as steady without introducing tidal cycle and by assuming a high kinematic eddy viscosity as stated earlier. The program was executed (cold start) by assuming initial conditions and values of independent variables were obtained. These values and a lower kinematic eddy viscosity value were used for next run i.e., for hot start. By repeating this procedure and reducing the kinematic eddy viscosity to about 0.930 sq.m/s the X and Y velocities and water surface elevations were estimated to arrive at the steady state results .

Semi diurnal cycle is applied at the mouth end to simulate the unsteady hydrodynamic conditions.

6.0 ANALYSIS & RESULTS

FESWMS is applied to the last 10 km stretch of the Vasishta Godavari stream at the Godavari delta formed due to esturine and fluvial hydrodynamic actions over a long period. The study area is simulated as a diverging shallow channel with a width of 750m at the upstream side and enlarging to 900m at the Bay end. Further characteristics of the study area are described elsewhere.

To start with a 'cold start' procedure is adopted for steady state since the details on initial conditions are not readily available. The output flow data file is used to further solve the steady state condition of the problem by 'hot start'. The output of this run is used as initial data file for the unsteady state condition wherein the hydrodynamic effect of tide was simulated. To arrive at convergence, instead of considering the whole tidal cycle in a single instance the effect is brought in by steps. The semi-diurnal tide considered for the present study is shown in fig.5 as given by Rao et al. No wind effect is considered in the present study.

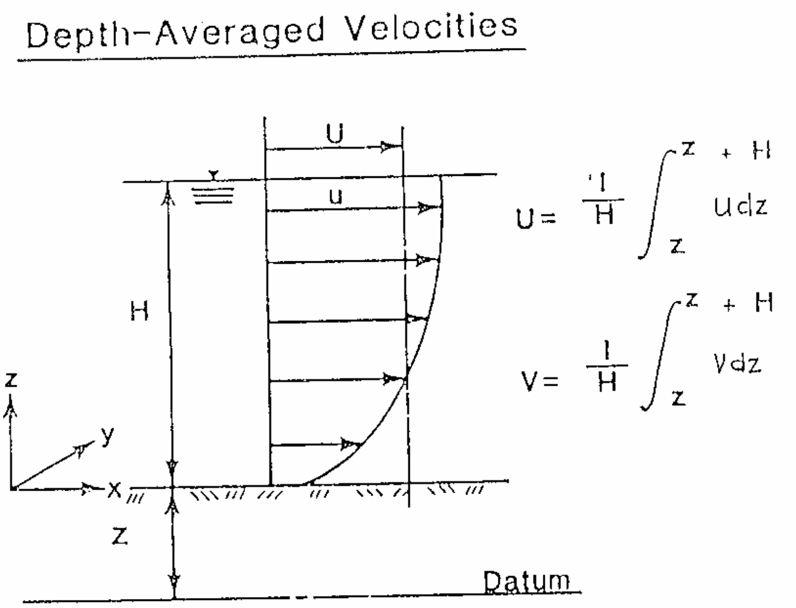

Fig.4 Illustration of Depth Averaged Velecity

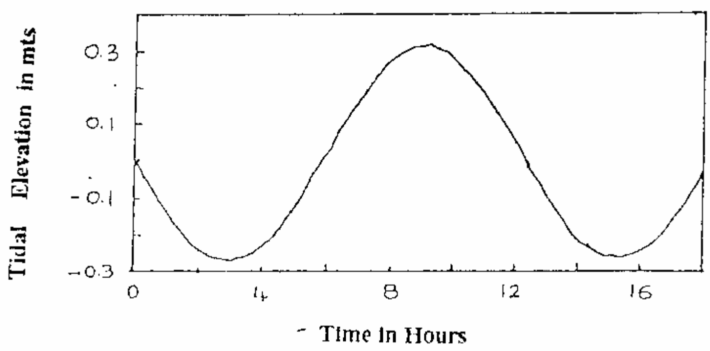

Fig.5 The Semi diurnal Tide

The 'ANOMOD' module is used to describe the results in tabular as well as graphical pattern. The output from the above unsteady 'FLOMOD' run is used for the ANOMOD module subsequently. The output file of the analysis is enclosed as Annexure-I. Here the element wise detailed information like connecting nodes, property codes and area covered are given. Also node wise information like coordinates, grow elevation are given. The primary flow data information nodewise like velocities, depth of flow, water surface elevation at a time duration of 3-hour interval are also presented for 3 hours, 6 hours, 9 hours, 12 hours and 15 hours. It is to be noted that the tidal cycle is approximately 12 hour period.

PLOTS :

The surface water level contours for 3 hour, 6 hour, 9 hour, 12 hour and 15 hour are shown in Fig.6 to 10.The gridline plots showing the velocity vectors at 3 hour, 6 hour, 9 hour, 12 hour and 15 hour on a scale of 1" = 2.5 m/s are shown in Fig.11 to 15. From these figures it can be observed that when the tide is high i.e., at 9 hour period the velocities are minimum in the middle of the stream. The small variation in the velocity over the 12 hour tidal period indicates the stream behaved as a fluivial or river dominated one, which is true for a stream in floods, which is the case at present. In other words it can be interpreted that there is a very less tidal domination in the reach.

7.0 CONCLUSIONS :

An attempt is made in this study to undertake surface water modeling to simulate the water levels in the mouth portion of Vasishta Godavari by taking the tidal effect during a flood season, by using the FESWMS advocated by USGS. In the absence of detailed bathymetric information of the area, the description given in the literature by others is adopted as a reach uniformly enlarging shallow channel. The objective is to simulate the surface water flow for a flood discharge of 2,35,000 cusecs or 6654.46 cumecs, under the effect of semi-diurnal tide at the bay end. The tables and plots presented for a time period of 3 hours have shown that the model is able to reflect the tidal effect in the reach. Since the gauge observations are not available , the results could not be compared to fine tune the model parameters. Though, it is possible to develop an operational model using FESWMS, the availability of the observed flow data and detailed bathymetric and topographic information under different flow scenarios is very important. However, gathering such information is not only expensive but also strenuous due to the logistics and the situations.

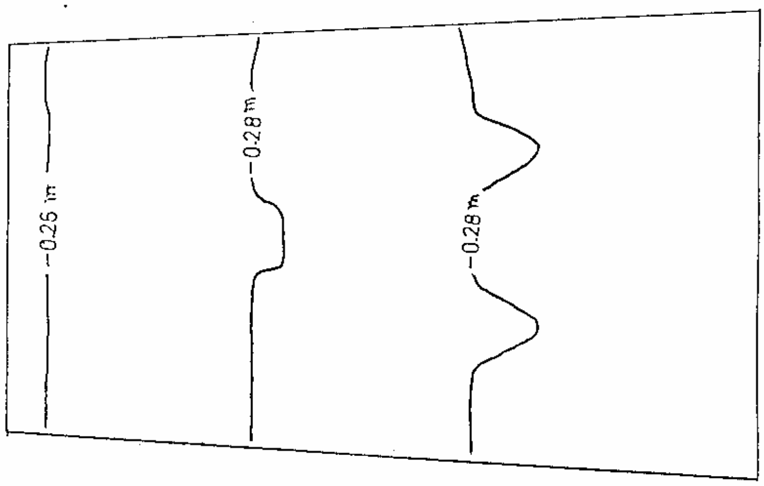

Fig.6 The Surface Water Level Contours for 3-hr duration

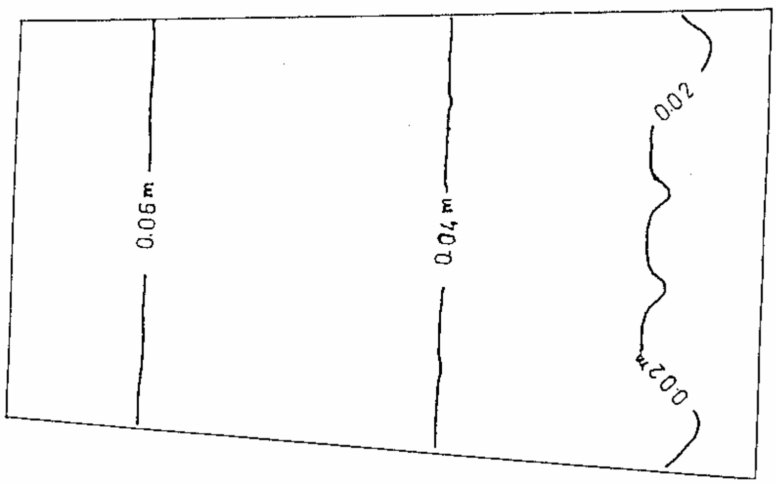

Fig.7 The Surface Water Level Contours for 6-hr duration

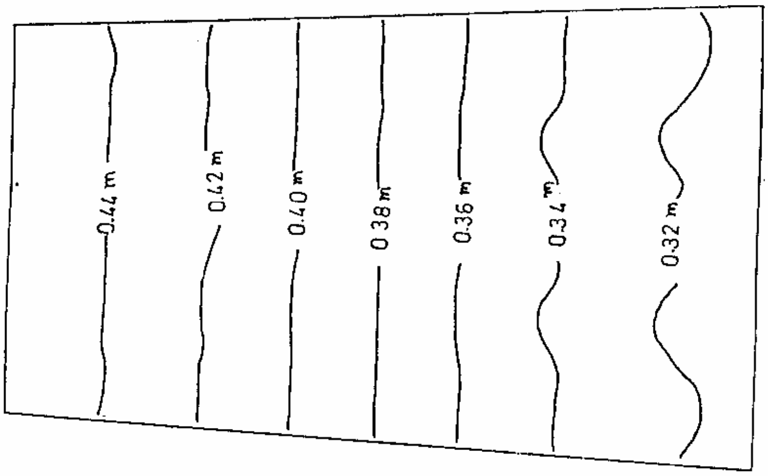

Fig.8 **The Surface Water Level Contours for 9-hr duration**

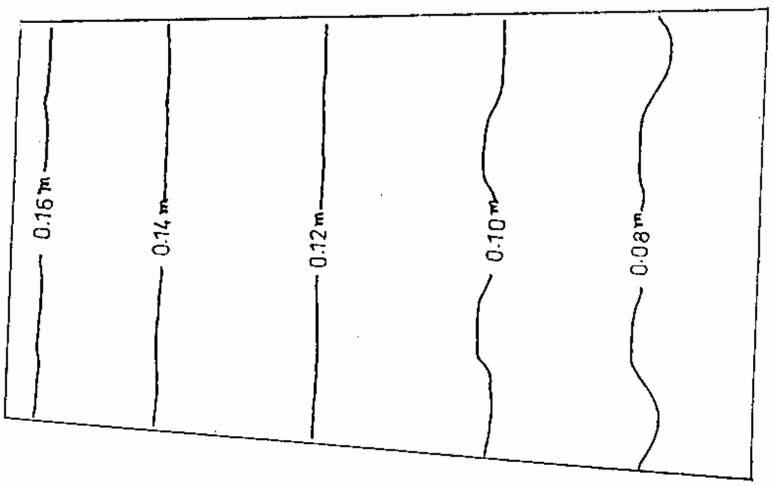

Fig.9 **The Surface Water Level Contours for 12-hr duration**

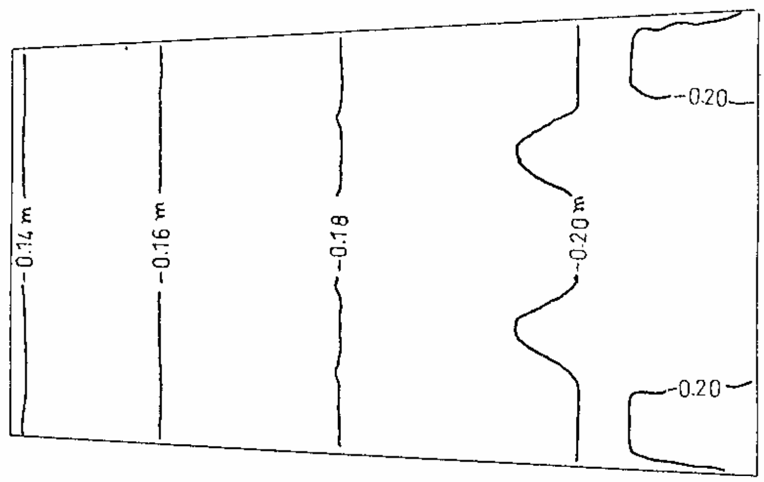

Fig.10 The Surface Water Level Contours for 15-hr duration

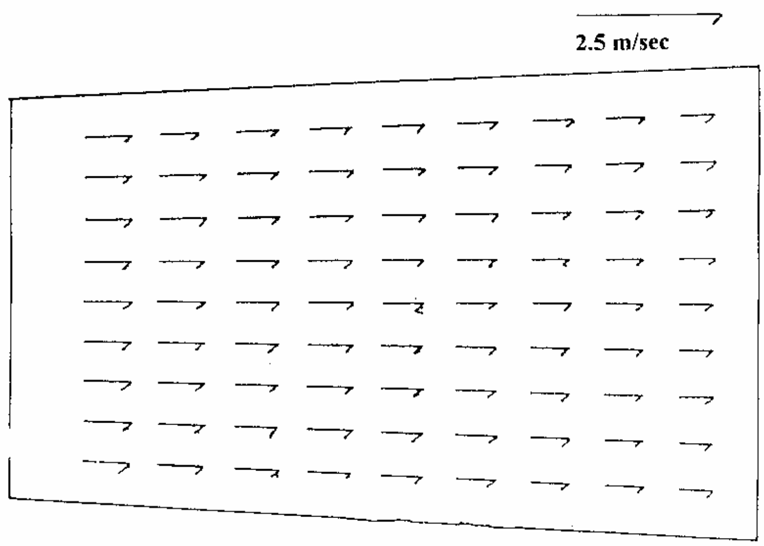

Fig. 11 Gridline Points Showing the Velocity vectors at 3-hr

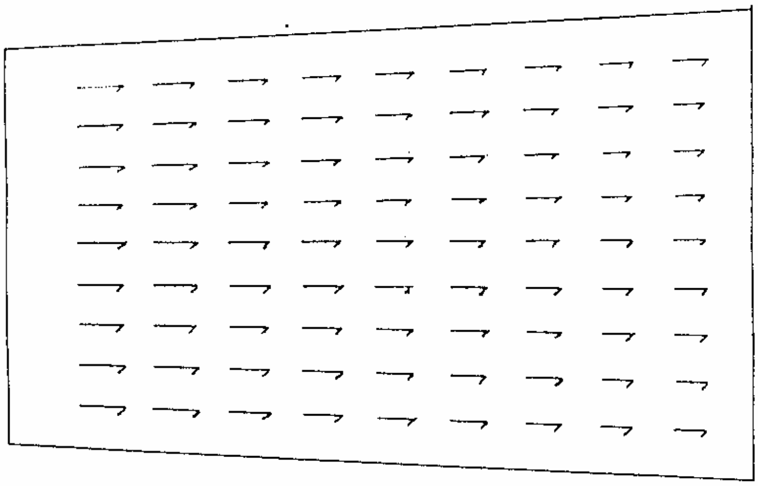

Fig. 12 Gridline Points Showing the Velocity vectors at 6-hr

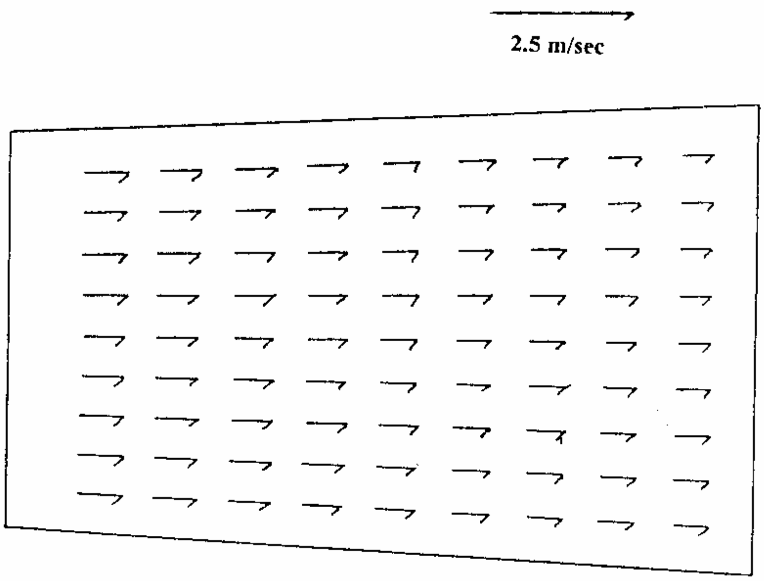

Fig. 13 Gridline Points Showing the Velocity vectors at 9-hr

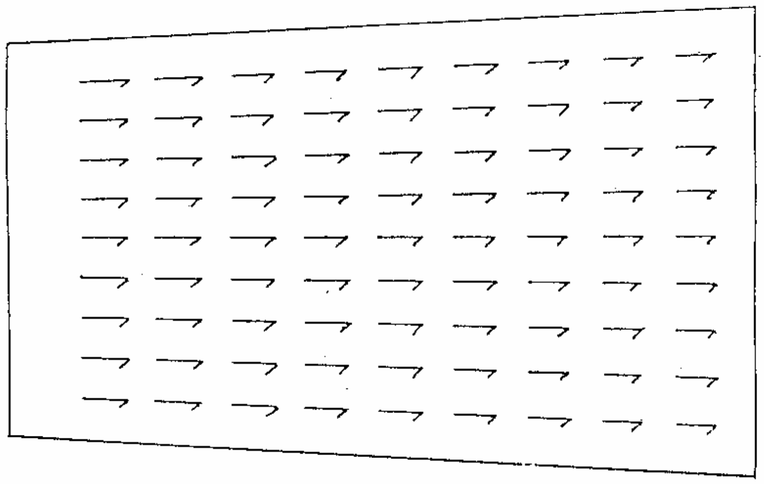

Fig. 14 **Gridline Points Showing the Velocity vectors at 12-hr**

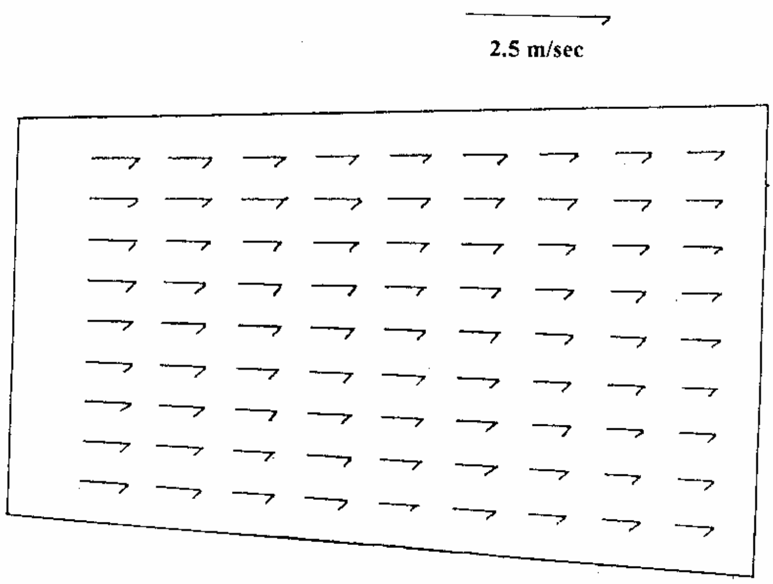

Fig. 15 **Gridline Points Showing the Velocity vectors at 15-hr**

The results arrived at on the water surface elevations may be useful in the design of embankments and the velocity vectors in the x and y directions will help in modeling sediment transport. Attempts were made to study the effect of tidal surge under flood conditions of the river unsuccessfully. May be due to the incompatibility of the grid size or due to change of flow parameters rapidly difficulties are noticed in the convergence of the problem. Hence the network may have to be refined and further attempts are required.

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ANNEXURE I

*** ELEMENT DATA ***

ELMT NO	NODES (COUNTERCLOCKWISE) 1	2	3	4	5	6	7	8	9	PROP CODE	AREA (M2)
1	1	2	3	14	25	24	23	12	13	1	306000.00
2	3	4	5	16	27	26	25	14	15	1	318000.00
3	5	6	7	18	29	28	27	16	17	1	330000.00
4	7	8	9	20	31	30	29	18	19	1	342000.00
5	9	10	11	22	33	32	31	20	21	1	354000.00
6	23	24	25	36	47	46	45	34	35	1	306000.00
7	25	26	27	38	49	48	47	36	37	1	318000.00
8	27	28	29	40	51	50	49	38	39	1	330000.00
9	29	30	31	42	53	52	51	40	41	1	342000.00
10	31	32	33	44	55	54	53	42	43	1	354000.00
11	45	46	47	58	69	68	67	56	57	1	306000.00
12	47	48	49	60	71	70	69	58	59	1	318000.00
13	49	50	51	62	73	72	71	60	61	1	330000.00
14	51	52	53	64	75	74	73	62	63	1	342000.00
15	53	54	55	66	77	76	75	64	65	1	354000.00
16	67	68	69	80	91	90	89	78	79	1	306000.00
17	69	70	71	82	93	92	91	80	81	1	318000.00
18	71	72	73	84	95	94	93	82	83	1	330000.00
19	73	74	75	86	97	96	95	84	85	1	342000.00
20	75	76	77	88	99	98	97	86	87	1	354000.00
21	89	90	91	102	113	112	111	100	101	1	306000.00
22	91	92	93	104	115	114	113	102	103	1	318000.00
23	93	94	95	106	117	116	115	104	105	1	330000.00
24	95	96	97	108	119	118	117	106	107	1	342000.00
25	97	98	99	110	121	120	119	108	109	1	354000.00

*** NODE DATA ***

NODE NO.	X-COORD (M)	Y-COORD (M)	GRND (M)	CEIL (M)
1	.00	75.00	-10.63	.00
2	1000.00	67.50	-10.84	.00
3	2000.00	60.00	-11.05	.00
4	3000.00	52.50	-11.26	.00
5	4000.00	45.00	-11.48	.00
6	5000.00	37.50	-11.69	.00
7	6000.00	30.00	-11.90	.00
8	7000.00	22.50	-12.11	.00
9	8000.00	15.00	-12.32	.00
10	9000.00	7.50	-12.53	.00
11	10000.00	.00	-12.75	.00
12	.00	150.00	-11.01	.00
13	1000.00	144.00	-11.22	.00
14	2000.00	138.00	-11.44	.00
15	3000.00	132.00	-11.66	.00
16	4000.00	126.00	-11.88	.00
17	5000.00	120.00	-12.10	.00
18	6000.00	114.00	-12.32	.00
19	7000.00	108.00	-12.54	.00
20	8000.00	102.00	-12.75	.00
21	9000.00	96.00	-12.98	.00
22	10000.00	90.00	-13.20	.00
23	.00	225.00	-11.38	.00
24	1000.00	220.50	-11.60	.00
25	2000.00	216.00	-11.83	.00
26	3000.00	211.50	-12.06	.00
27	4000.00	207.00	-12.28	.00
28	5000.00	202.50	-12.51	.00
29	6000.00	198.00	-12.74	.00
30	7000.00	193.50	-12.97	.00
31	8000.00	189.00	-13.19	.00
32	9000.00	184.50	-13.42	.00
33	10000.00	180.00	-13.65	.00
34	.00	300.00	-11.76	.00
35	1000.00	297.00	-11.98	.00
36	2000.00	294.00	-12.22	.00
37	3000.00	291.00	-12.45	.00
38	4000.00	288.00	-12.69	.00
39	5000.00	285.00	-12.93	.00
40	6000.00	282.00	-13.16	.00
41	7000.00	279.00	-13.40	.00
42	8000.00	276.00	-13.63	.00
43	9000.00	273.00	-13.86	.00
44	10000.00	270.00	-14.10	.00
45	.00	375.00	-12.13	.00
46	1000.00	373.50	-12.37	.00
47	2000.00	372.00	-12.61	.00
48	3000.00	370.50	-12.85	.00
49	4000.00	369.00	-13.10	.00
50	5000.00	367.50	-13.34	.00

51	6000.00	366.00	-13.58	.00
52	7000.00	364.50	-13.82	.0C
53	8000.00	363.00	-14.06	.00
54	9000.00	361.50	-14.31	.00
55	10000.00	360.00	-14.55	.00
56	.00	450.00	-12.13	.00
57	1000.00	450.00	-12.75	.00
58	2000.00	450.00	-12.61	.00
59	3000.00	450.00	-13.25	.00
60	4000.00	450.00	-13.10	.00
61	5000.00	450.00	-13.75	.00
62	6000.00	450.00	-13.58	.00
63	7000.00	450.00	-14.25	.00
64	8000.00	450.00	-14.06	.00
65	9000.00	450.00	-14.75	.00
66	10000.00	450.00	-14.55	.00
67	.00	525.00	-12.13	.00
68	1000.00	526.50	-12.37	.00
69	2000.00	528.00	-12.61	.00
70	3000.00	529.50	-12.85	.00
71	4000.00	531.00	-13.10	.00
72	5000.00	532.50	-13.34	.00
73	6000.00	534.00	-13.58	.00
74	7000.00	535.50	-13.82	.00
75	8000.00	537.00	-14.06	.00
76	9000.00	538.50	-14.31	.00
77	10000.00	540.00	-14.55	.00
78	.00	600.00	-11.76	.00
79	1000.00	603.00	-11.98	.00
80	2000.00	606.00	-12.22	.00
81	3000.00	609.00	-12.45	.00
82	4000.00	612.00	-12.69	.00
83	5000.00	615.00	-12.93	.00
84	6000.00	618.00	-13.16	.00
85	7000.00	621.00	-13.40	.00
86	8000.00	624.00	-13.63	.00
87	9000.00	627.00	-13.86	.00
88	10000.00	630.00	-14.10	.00
89	.00	675.00	-11.38	.00
90	1000.00	679.50	-11.60	.00
91	2000.00	684.00	-11.83	.00
92	3000.00	688.50	-12.06	.00
93	4000.00	693.00	-12.28	.00
94	5000.00	697.50	-12.51	.00
95	6000.00	702.00	-12.74	.00
96	7000.00	706.50	-12.97	.00
97	8000.00	711.00	-13.19	.00
98	9000.00	715.50	-13.42	.00
99	10000.00	720.00	-13.65	.00
00	.00	750.00	-11.01	.00

101	1000.00	756.00	-11.22	.00
102	2000.00	762.00	-11.44	.00
103	3000.00	768.00	-11.66	.00
104	4000.00	774.00	-11.88	.00
105	5000.00	780.00	-12.10	.00
106	6000.00	786.00	-12.32	.00
107	7000.00	792.00	-12.54	.00
108	8000.00	798.00	-12.75	.00
109	9000.00	804.00	-12.98	.00
110	10000.00	810.00	-13.20	.00
111	.00	825.00	-10.63	.00
112	1000.00	832.50	-10.84	.00
113	2000.00	840.00	-11.05	.00
114	3000.00	847.50	-11.26	.00
115	4000.00	855.00	-11.48	.00
116	5000.00	862.50	-11.69	.00
117	6000.00	870.00	-11.90	.00
118	7000.00	877.50	-12.11	.00
119	8000.00	885.00	-12.32	.00
120	9000.00	892.50	-12.53	.00
121	10000.00	900.00	-12.75	.00

*** FLOW DATA (PRIMARY) ***

*** SIMULATION TIME: 3.000 HOURS ***

NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)	NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)
1	.789	-.006	10.375	-.255	62	.622	.000	13.299	-.281
2	.772	-.006	10.575	-.265	63	.594	.000	13.544	-.706
3	.757	-.006	10.775	-.275	64	.580	.000	13.789	-.271
4	.684	-.005	10.986	-.274	65	.545	.000	14.039	-.711
5	.655	-.005	11.197	-.283	66	.522	.000	14.290	-.260
6	.657	-.005	11.408	-.282	67	.787	.000	11.875	-.255
7	.637	-.005	11.619	-.281	68	.757	.002	12.105	-.265
8	.581	-.004	11.834	-.276	69	.727	.000	12.335	-.275
9	.557	-.004	12.049	-.271	70	.703	.000	12.576	-.274
10	.552	-.004	12.269	-.261	71	.681	.001	12.817	-.283
11	.544	-.004	12.490	-.260	72	.644	.002	13.058	-.282
12	.784	.000	10.750	-.260	73	.624	.000	13.299	-.281
13	.757	-.008	10.958	-.262	74	.595	.000	13.544	-.276
14	.737	-.003	11.165	-.275	75	.578	.001	13.789	-.271
15	.699	.000	11.381	-.279	76	.542	.002	14.039	-.271
16	.667	-.006	11.597	-.283	77	.520	.002	14.290	-.260
17	.644	-.007	11.818	-.282	78	.788	.000	11.500	-.260
18	.630	-.003	12.039	-.281	79	.758	.004	11.723	-.257
19	.591	-.001	12.262	-.278	80	.724	.001	11.945	-.275
20	.568	-.004	12.484	-.266	81	.700	.000	12.176	-.274
21	.542	-.006	12.712	-.268	82	.682	.002	12.407	-.283
22	.531	-.005	12.940	-.260	83	.647	.004	12.643	-.287
23	.786	.000	11.125	-.255	84	.622	.001	12.879	-.281
24	.750	-.006	11.340	-.260	85	.593	.000	13.117	-.283
25	.719	-.004	11.555	-.275	86	.578	.002	13.354	-.276
26	.705	.000	11.776	-.284	87	.545	.004	13.597	-.263
27	.683	-.003	11.997	-.283	88	.523	.004	13.840	-.260
28	.641	-.005	12.228	-.282	89	.786	.000	11.125	-.255
29	.620	-.003	12.459	-.281	90	.750	.006	11.340	-.260
30	.595	.000	12.689	-.281	91	.722	.003	11.555	-.275
31	.579	-.003	12.919	-.271	92	.704	.000	11.776	-.284
32	.541	-.005	13.154	-.266	93	.682	.003	11.997	-.283
33	.522	-.005	13.390	-.260	94	.641	.006	12.228	-.282
34	.788	.000	11.500	-.260	95	.622	.003	12.459	-.281
35	.756	-.004	11.723	-.257	96	.595	.000	12.689	-.281
36	.723	-.002	11.945	-.275	97	.577	.002	12.919	-.271
37	.700	.000	12.176	-.274	98	.541	.005	13.154	-.266
38	.662	-.003	12.407	-.283	99	.524	.005	13.390	-.260
39	.647	-.004	12.643	-.287	100	.784	.000	10.750	-.260
40	.622	-.002	12.879	-.281	101	.761	.008	10.958	-.262
41	.592	.000	13.117	-.283	102	.738	.003	11.165	-.275
42	.578	-.002	13.354	-.276	103	.700	.001	11.381	-.279
43	.544	-.003	13.597	-.263	104	.666	.005	11.597	-.283
44	.522	-.003	13.840	-.260	105	.644	.007	11.818	-.282
45	.787	.000	11.875	-.255	106	.630	.002	12.039	-.281
46	.755	-.001	12.105	-.265	107	.591	.001	12.262	-.278
47	.727	-.001	12.335	-.275	108	.566	.004	12.484	-.266
48	.703	.000	12.576	-.274	109	.542	.006	12.712	-.268
49	.681	-.002	12.817	-.283	110	.533	.005	12.940	-.260
50	.644	-.002	13.058	-.282	111	.789	.006	10.375	-.255
51	.623	-.001	13.299	-.281	112	.781	.006	10.575	-.265
52	.595	.000	13.544	-.276	113	.751	.006	10.776	-.274
53	.579	-.001	13.789	-.271	114	.689	.005	10.986	-.274
54	.543	-.001	14.039	-.271	115	.653	.005	11.197	-.283
55	.520	-.002	14.290	-.260	116	.657	.005	11.408	-.282
56	.789	.000	11.875	-.255	117	.637	.005	11.620	-.280
57	.757	.000	12.105	-.645	118	.582	.004	11.834	-.276
58	.727	-.001	12.335	-.275	119	.557	.004	12.049	-.271
59	.704	.000	12.576	-.674	120	.552	.004	12.269	-.261
60	.682	.000	12.817	-.283	121	.545	.004	12.490	-.260
61	.645	.000	13.058	-.692					

*** SIMULATION TIME: 6.000 HOURS ***

NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)	NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)
1	.767	-.006	10.704	.074	62	.548	.000	13.619	.039
2	.734	-.006	10.906	.066	63	.522	.000	13.852	-.398
3	.711	-.005	11.108	.058	64	.504	.000	14.086	.026
4	.623	-.005	11.318	.058	65	.484	.000	14.323	-.427
5	.594	-.004	11.528	.048	66	.456	.000	14.560	.010
6	.581	-.004	11.733	.043	67	.764	.000	12.204	.074
7	.561	-.004	11.939	.039	68	.716	.002	12.436	.066
8	.511	-.004	12.142	.032	69	.685	.000	12.668	.058
9	.483	-.004	12.346	.026	70	.638	.000	12.908	.058
10	.491	-.004	12.553	.023	71	.617	.001	13.148	.048
11	.481	-.004	12.760	.010	72	.569	.002	13.383	.043
12	.762	.000	11.079	.069	73	.548	.000	13.619	.039
13	.716	-.008	11.289	.069	74	.523	.000	13.852	.032
14	.694	-.003	11.498	.058	75	.505	.001	14.086	.026
15	.634	.000	11.713	.053	76	.483	.002	14.323	.013
16	.603	-.005	11.928	.048	77	.456	.002	14.560	.010
17	.569	-.006	12.143	.043	78	.766	.000	11.829	.069
18	.555	-.002	12.359	.039	79	.718	.004	12.054	.074
19	.519	-.001	12.570	.030	80	.681	.001	12.278	.058
20	.493	-.004	12.781	.031	81	.636	.000	12.508	.058
21	.484	-.006	12.996	.016	82	.619	.002	12.738	.048
22	.468	-.005	13.210	.010	83	.571	.004	12.968	.038
23	.764	.000	11.454	.074	84	.546	.001	13.199	.039
24	.710	-.005	11.671	.071	85	.521	.000	13.425	.025
25	.676	-.004	11.888	.058	86	.505	.001	13.651	.021
26	.640	.000	12.108	.048	87	.487	.004	13.881	.021
27	.618	-.003	12.328	.048	88	.459	.004	14.110	.010
28	.566	-.005	12.553	.043	89	.764	.000	11.454	.074
29	.546	-.003	12.779	.039	90	.711	.006	11.671	.071
30	.522	.000	12.997	.027	91	.679	.003	11.888	.058
31	.504	-.002	13.216	.026	92	.640	.000	12.108	.048
32	.482	-.005	13.438	.018	93	.617	.002	12.328	.048
33	.457	-.005	13.660	.010	94	.567	.006	12.553	.043
34	.766	.000	11.829	.069	95	.547	.002	12.779	.039
35	.718	-.004	12.054	.074	96	.522	.000	12.997	.027
36	.681	-.002	12.278	.058	97	.503	.002	13.216	.026
37	.636	.000	12.508	.058	98	.482	.005	13.438	.018
38	.618	-.003	12.738	.048	99	.458	.005	13.660	.010
39	.572	-.003	12.968	.038	100	.762	.000	11.079	.069
40	.548	-.001	13.199	.039	101	.722	.008	11.289	.069
41	.520	.000	13.425	.025	102	.696	.002	11.498	.058
42	.504	-.002	13.651	.021	103	.636	.000	11.713	.053
43	.486	-.003	13.881	.021	104	.602	.005	11.928	.048
44	.459	-.003	14.110	.010	105	.570	.007	12.143	.043
45	.764	.000	12.204	.074	106	.555	.002	12.359	.039
46	.717	-.002	12.436	.066	107	.519	.000	12.570	.030
47	.684	-.001	12.668	.058	108	.492	.003	12.781	.031
48	.638	.000	12.908	.058	109	.483	.006	12.995	.015
49	.617	-.001	13.148	.048	110	.469	.005	13.210	.010
50	.569	-.002	13.383	.043	111	.767	.006	10.704	.074
51	.548	-.001	13.619	.039	112	.741	.006	10.906	.066
52	.523	.000	13.852	.032	113	.710	.005	11.108	.058
53	.504	-.001	14.086	.026	114	.626	.005	11.318	.058
54	.485	-.002	14.323	.013	115	.591	.004	11.528	.048
55	.457	-.002	14.560	.010	116	.581	.004	11.733	.043
56	.767	.000	12.204	.074	117	.562	.004	11.939	.039
57	.717	.000	12.436	-.314	118	.510	.004	12.142	.032
58	.683	.000	12.668	.058	119	.482	.004	12.346	.026
59	.639	.000	12.908	-.342	120	.493	.004	12.553	.023
60	.618	.000	13.148	.048	121	.483	.004	12.760	.010
61	.569	.000	13.383	-.367					

*** SIMULATION TIME: 9.000 HOURS ***

NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)	NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)
1	.743	-.006	11.087	.457	62	.588	.000	13.941	.361
2	.724	-.005	11.284	.444	63	.577	.000	14.166	-.084
3	.716	-.005	11.480	.430	64	.557	.000	14.391	.331
4	.646	-.005	11.678	.418	65	.531	.000	14.625	-.125
5	.614	-.005	11.877	.397	66	.515	.000	14.860	.310
6	.629	-.005	12.069	.379	67	.740	.000	12.588	.458
7	.602	-.005	12.261	.361	68	.708	.002	12.814	.444
8	.567	-.004	12.456	.346	69	.689	.001	13.040	.430
9	.538	-.004	12.651	.331	70	.661	.000	13.268	.418
10	.538	-.004	12.855	.325	71	.637	.001	13.497	.397
11	.536	-.004	13.060	.310	72	.617	.002	13.719	.379
12	.738	.000	11.463	.453	73	.590	.000	13.941	.361
13	.708	-.007	11.666	.446	74	.579	.000	14.166	.346
14	.700	-.003	11.870	.430	75	.556	.001	14.391	.331
15	.658	.000	12.073	.413	76	.531	.002	14.625	.315
16	.626	-.005	12.277	.397	77	.515	.002	14.860	.310
17	.616	-.006	12.479	.379	78	.741	.000	12.213	.453
18	.597	-.002	12.681	.361	79	.710	.004	12.431	.451
19	.574	-.001	12.884	.344	80	.685	.002	12.650	.430
20	.547	-.004	13.086	.336	81	.659	.000	12.868	.418
21	.531	-.006	13.298	.318	82	.639	.002	13.087	.397
22	.525	-.004	13.510	.310	83	.618	.004	13.304	.374
23	.740	.000	11.838	.458	84	.587	.001	13.521	.361
24	.704	-.005	12.049	.449	85	.576	.000	13.739	.339
25	.683	-.004	12.260	.430	86	.558	.002	13.956	.326
26	.663	.000	12.468	.408	87	.534	.004	14.183	.323
27	.641	-.003	12.677	.397	88	.517	.004	14.410	.310
28	.613	-.005	12.889	.379	89	.740	.000	11.838	.458
29	.588	-.003	13.101	.361	90	.704	.006	12.049	.449
30	.578	.000	13.311	.341	91	.685	.003	12.260	.430
31	.556	-.003	13.521	.331	92	.663	.000	12.468	.408
32	.530	-.005	13.740	.320	93	.640	.003	12.677	.397
33	.516	-.004	13.960	.310	94	.613	.006	12.889	.379
34	.741	.000	12.213	.453	95	.587	.002	13.101	.361
35	.710	-.003	12.431	.451	96	.579	.000	13.311	.341
36	.686	-.002	12.650	.430	97	.556	.002	13.521	.331
37	.659	.000	12.868	.418	98	.529	.005	13.740	.320
38	.638	-.002	13.087	.397	99	.517	.005	13.960	.310
39	.619	-.003	13.304	.374	100	.738	.000	11.463	.453
40	.586	-.002	13.521	.361	101	.712	.008	11.666	.446
41	.577	.000	13.739	.339	102	.702	.003	11.870	.430
42	.557	-.002	13.956	.326	103	.660	.001	12.073	.413
43	.533	-.003	14.183	.323	104	.624	.005	12.277	.397
44	.517	-.003	14.410	.310	105	.618	.007	12.479	.379
45	.740	.000	12.588	.458	106	.597	.002	12.681	.361
46	.708	-.001	12.814	.444	107	.575	.001	12.884	.344
47	.688	-.001	13.040	.430	108	.544	.004	13.086	.336
48	.661	.000	13.268	.418	109	.530	.006	13.298	.318
49	.638	-.001	13.497	.397	110	.527	.005	13.510	.310
50	.617	-.002	13.719	.379	111	.743	.006	11.087	.457
51	.588	-.001	13.941	.361	112	.731	.005	11.284	.444
52	.578	.000	14.166	.346	113	.714	.005	11.480	.430
53	.556	-.001	14.391	.331	114	.651	.005	11.678	.418
54	.531	-.002	14.625	.315	115	.612	.005	11.877	.397
55	.516	-.002	14.860	.310	116	.629	.005	12.069	.379
56	.742	.000	12.588	.458	117	.603	.005	12.261	.361
57	.709	.000	12.814	.064	118	.566	.004	12.456	.346
58	.689	.000	13.040	.430	119	.538	.004	12.651	.331
59	.662	.000	13.268	.018	120	.540	.004	12.855	.325
60	.642	.000	13.497	.397	121	.540	.004	13.060	.310
61	.616	.000	13.719	-.031					

*** SIMULATION TIME: 12.000 HOURS ***

NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)	NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)
1	.761	-.006	10.795	.165	62	.655	.000	13.684	.104
2	.758	-.006	10.993	.153	63	.641	.000	13.916	-.334
3	.749	-.006	11.190	.140	64	.631	.000	14.147	.087
4	.698	-.005	11.396	.136	65	.607	.000	14.378	-.372
5	.666	-.005	11.601	.121	66	.588	.000	14.610	.060
6	.688	-.005	11.803	.113	67	.758	.000	12.295	.165
7	.672	-.005	12.004	.104	68	.743	.002	12.523	.153
8	.628	-.005	12.206	.096	69	.722	.001	12.750	.140
9	.613	-.005	12.407	.087	70	.714	.000	12.986	.136
10	.614	-.005	12.608	.078	71	.693	.001	13.221	.121
11	.608	-.005	12.810	.060	72	.673	.002	13.453	.113
12	.757	.000	11.170	.160	73	.659	.001	13.684	.104
13	.742	-.007	11.375	.155	74	.640	.000	13.916	.096
14	.732	-.003	11.580	.140	75	.630	.001	14.147	.087
15	.711	-.001	11.791	.131	76	.606	.002	14.378	.068
16	.678	-.005	12.001	.121	77	.587	.002	14.610	.060
17	.674	-.007	12.213	.113	78	.760	.000	11.920	.160
18	.666	-.003	12.424	.104	79	.742	.004	12.140	.160
19	.636	-.001	12.633	.093	80	.721	.002	12.360	.140
20	.620	-.005	12.842	.092	81	.711	.000	12.586	.136
21	.607	-.006	13.051	.071	82	.694	.002	12.811	.121
22	.598	-.005	13.260	.060	83	.676	.004	13.038	.108
23	.758	.000	11.545	.165	84	.657	.001	13.264	.104
24	.736	-.005	11.758	.158	85	.637	.000	13.488	.088
25	.716	-.004	11.970	.140	86	.631	.002	13.712	.082
26	.715	.000	12.186	.126	87	.610	.004	13.936	.076
27	.692	-.003	12.401	.121	88	.590	.004	14.160	.060
28	.672	-.005	12.623	.113	89	.758	.000	11.545	.165
29	.657	-.003	12.844	.104	90	.735	.006	11.758	.158
30	.640	.000	13.061	.091	91	.717	.003	11.970	.140
31	.629	-.003	13.277	.087	92	.716	.000	12.186	.126
32	.606	-.005	13.493	.073	93	.693	.003	12.401	.121
33	.589	-.004	13.710	.060	94	.672	.006	12.623	.113
34	.760	.000	11.920	.160	95	.656	.003	12.844	.104
35	.742	-.003	12.140	.160	96	.641	.000	13.061	.091
36	.720	-.002	12.360	.140	97	.629	.002	13.277	.087
37	.711	.000	12.586	.136	98	.605	.006	13.493	.073
38	.694	-.003	12.811	.121	99	.591	.005	13.710	.060
39	.676	-.004	13.038	.108	100	.757	.000	11.170	.160
40	.657	-.002	13.264	.104	101	.746	.008	11.375	.155
41	.638	.000	13.488	.088	102	.733	.003	11.580	.140
42	.630	-.002	13.712	.082	103	.713	.001	11.791	.131
43	.609	-.003	13.936	.076	104	.677	.005	12.001	.121
44	.590	-.003	14.160	.060	105	.675	.007	12.213	.113
45	.758	.000	12.295	.165	106	.665	.003	12.424	.104
46	.742	-.002	12.523	.153	107	.637	.001	12.633	.093
47	.722	-.001	12.750	.140	108	.617	.004	12.842	.092
48	.714	.000	12.986	.136	109	.607	.007	13.051	.071
49	.691	-.002	13.221	.121	110	.601	.005	13.260	.060
50	.674	-.002	13.453	.113	111	.761	.006	10.795	.165
51	.657	-.001	13.684	.104	112	.764	.006	10.993	.153
52	.640	.000	13.916	.096	113	.745	.006	11.190	.140
53	.629	-.002	14.147	.087	114	.703	.005	11.396	.136
54	.607	-.002	14.378	.068	115	.664	.005	11.601	.121
55	.589	-.001	14.610	.060	116	.687	.005	11.803	.113
56	.761	.000	12.295	.165	117	.671	.005	12.004	.104
57	.744	.000	12.523	-.227	118	.628	.005	12.206	.096
58	.718	.000	12.750	.140	119	.611	.005	12.407	.087
59	.714	.000	12.986	-.264	120	.615	.005	12.608	.078
60	.692	.000	13.221	.121	121	.611	.005	12.810	.060
61	.676	.000	13.453	-.297					

*** SIMULATION TIME: 15.000 HOURS ***

NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)	NODE NO.	X-VEL (M/S)	Y-VEL (M/S)	DEPTH (M)	WSEL (M)
1	.781	-.006	10.492	-.138	62	.636	.000	13.388	-.192
2	.763	-.006	10.691	-.149	63	.620	.000	13.623	-.627
3	.747	-.006	10.890	-.160	64	.605	.000	13.858	-.202
4	.681	-.005	11.097	-.163	65	.579	.000	14.104	-.646
5	.658	-.005	11.303	-.177	66	.559	.000	14.350	-.200
6	.660	-.005	11.506	-.184	67	.779	.000	11.992	-.138
7	.652	-.005	11.708	-.192	68	.747	.002	12.221	-.149
8	.606	-.005	11.913	-.197	69	.720	.001	12.450	-.160
9	.582	-.004	12.118	-.202	70	.696	.000	12.687	-.163
10	.587	-.004	12.334	-.196	71	.682	.001	12.923	-.177
11	.580	-.004	12.550	-.200	72	.651	.002	13.156	-.184
12	.776	.000	10.867	-.143	73	.637	.001	13.388	-.192
13	.748	-.008	11.073	-.147	74	.621	.000	13.623	-.197
14	.730	-.003	11.280	-.160	75	.602	.001	13.858	-.202
15	.693	-.001	11.492	-.168	76	.578	.002	14.104	-.206
16	.668	-.005	11.703	-.177	77	.558	.002	14.350	-.200
17	.650	-.007	11.916	-.184	78	.780	.000	11.617	-.143
18	.646	-.003	12.128	-.192	79	.746	.004	11.838	-.142
19	.615	-.001	12.341	-.199	80	.720	.002	12.060	-.160
20	.591	-.004	12.553	-.197	81	.694	.000	12.287	-.163
21	.580	-.006	12.776	-.204	82	.684	.002	12.513	-.177
22	.570	-.005	13.000	-.200	83	.652	.004	12.741	-.18[illegible]
23	.778	.000	11.242	-.138	84	.636	.001	12.968	-.192
24	.742	-.005	11.456	-.144	85	.617	.000	13.196	-.204
25	.714	-.004	11.670	-.160	86	.603	.002	13.423	-.207
26	.699	.000	11.887	-.173	87	.582	.004	13.661	-.199
27	.683	-.003	12.103	-.177	88	.560	.004	13.900	-.200
28	.648	-.006	12.326	-.184	89	.778	.000	11.242	-.138
29	.637	-.003	12.548	-.192	90	.740	.006	11.456	-.144
30	.619	.000	12.768	-.202	91	.715	.003	11.670	-.160
31	.602	-.003	12.988	-.202	92	.700	.000	11.887	-.173
32	.578	-.005	13.219	-.201	93	.683	.002	12.103	-.177
33	.561	-.005	13.450	-.200	94	.647	.006	12.326	-.184
34	.780	.000	11.617	-.143	95	.637	.002	12.548	-.192
35	.747	-.004	11.838	-.142	96	.620	.000	12.768	-.202
36	.719	-.002	12.060	-.160	97	.602	.002	12.988	-.202
37	.693	.000	12.287	-.163	98	.577	.006	13.219	-.201
38	.684	-.002	12.513	-.177	99	.561	.005	13.450	-.200
39	.652	-.004	12.741	-.189	100	.776	.000	10.867	-.143
40	.637	-.002	12.968	-.192	101	.753	.008	11.073	-.147
41	.617	.000	13.196	-.204	102	.730	.002	11.280	-.160
42	.602	-.002	13.423	-.207	103	.696	.001	11.492	-.168
43	.580	-.004	13.661	-.199	104	.666	.005	11.703	-.177
44	.560	-.003	13.900	-.200	105	.652	.007	11.916	-.184
45	.779	.000	11.992	-.138	106	.645	.002	12.128	-.192
46	.748	-.002	12.221	-.149	107	.617	.001	12.341	-.199
47	.721	-.001	12.450	-.160	108	.588	.004	12.553	-.197
48	.697	.000	12.687	-.163	109	.579	.007	12.776	-.204
49	.682	-.002	12.923	-.177	110	.571	.005	13.000	-.200
50	.651	-.002	13.156	-.184	111	.781	.006	10.492	-.138
51	.637	-.001	13.388	-.192	112	.775	.006	10.691	-.149
52	.621	.000	13.623	-.197	113	.746	.006	10.890	-.160
53	.603	-.001	13.858	-.202	114	.686	.005	11.097	-.163
54	.579	-.002	14.104	-.206	115	.653	.005	11.303	-.177
55	.559	-.001	14.350	-.200	116	.662	.005	11.506	-.184
56	.781	.000	11.992	-.138	117	.652	.005	11.708	-.192
57	.750	.000	12.221	-.529	118	.606	.005	11.913	-.197
58	.717	.000	12.450	-.160	119	.582	.004	12.118	-.202
59	.699	.000	12.687	-.563	120	.588	.004	12.334	-.196
60	.684	.000	12.923	-.177	121	.584	.004	12.550	-.200
61	.653	.000	13.156	-.594					

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