DEVELOPMENT OF A COMPUTER PROGRAM FOR OPTIMUM DESIGN OF DIVERSION WEIRS

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ABSTRACT

DEVELOPMENT OF A COMPUTER PROGRAM FOR OPTIMUM DESIGN OF DIVERSION WEIRS

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A diversion weir is a headwork facility built across a river to raise the water level and to divert water for various purposes, such as irrigation, hydropower generation, etc. Diversion weirs with sidewise intakes are widely used in plain rivers. They are composed of many structural components which are designed for different purposes. In this thesis, a Windows-based, visual, user friendly program named WINDWEIR was developed in Visual Basic.NET programming language for the optimum design of a diversion weir with sidewise intake. It determines the overall dimensions of each of the components of the diversion weir and the total cost of the whole structure. It also performs stability analysis. It is such a flexible computer program that a design engineer can assess various dimensions of the structure from viewpoints of safety and economy by performing quick successive test runs to achieve an optimum solution among various alternatives.

Key words: Diversion weir, Sidewise Intake, Computer Aided Design.

ÖZ

REGÜLATÖRLERİN OPTİMUM TASARIMINA YÖNELİK BİR BİLGİSAYAR PROGRAMI GELİŞTİRME

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Regülatör, sulama, elektrik enerjisi üretimi, vb. amaçlarla akarsu seviyesini kabartarak akarsudan istenen miktarda suyun alınmasını sağlayan, akarsu üzerine inşaa edilen bir çevirme yapısıdır. Yandan alışlı regülatörler ova akarsularında sıkça kullanılmaktadır. Yandan alışlı regülatörler, değişik amaçlar için tasarlanan bir çok yapısal parçadan meydana gelmektedir. Bu tezde, yandan alışlı bir regülatörün optimum tasarımına yönelik, Visual Basic.Net programlama dilinde yazılmış WINDWEIR adlı, Windows işletim sistemi altında çalışan, görsel, kullanımı kolay bir bilgisayar programı geliştirilmiştir. Program, regülatörün her bir parçasının bütün boyutlarını ve tüm yapının toplam maliyetini belirlemekte ve yapının denge analizini yapmaktadır. Bu bilgisayar programı ayrıca, hızlı ardışık denemelerle bir tasarım mühendisinin değişik seçenekler arasından optimum çözüme ulaşabilmesi için yapının çeşitli boyutlarını güvenlik ve ekonomi açılarından değerlendirmesine olanak sağlayacak esnekliktedir.

Key words: Regülatör, Yandan Alışlı Priz, Bilgisayar Destekli Tasarım.

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF SYMBOLS

A : cross-sectional area of flow;

A_{bs} : base area of the spillway;

A_g : gross area at the beginning of intake;

A_n : net area through the rack bars;

A_{sh}: area of the shear plane;

B : bottom width at the beginning of main irrigation canal;

B_1 : bottom width at the end of intake;

B_{3n} : the net width of the channel at the entrance of the main canal;

B_s : width of the settling basin;

B_{sn} : net width at the entrance of the intake;

B_{sw} : width of the base slab of the sidewall;

b : bottom width of the diversion canal;

b_{op} : optimum bottom width of the diversion canal;

C : relative permeability of soil;

C_0 : design discharge coefficient for vertical faced ogee crest;

C_T : total cost of the diversion facility;

C_c : minor loss due to curvature;

C_{ch} : cost of diversion canal;

C_{core} : unit cost of embankment core construction;

C_{dc} : cost of downstream cofferdam;

C_e : unit cost of excavation;

C_{ex} : unit cost of expropriation;

C_{inc} : design discharge coefficient with sloping upstream face;

C_l : unit cost of canal lining;

C_{ma} : design discharge coefficient due to apron effect;

C_{me} : design discharge coefficient for varying heads;

C_{ms} : the design discharge coefficient due to submergence effect;

C_{om} : overall modified discharge coefficient due to USBR method;

C_{per} : unit cost of embankment pervious fill construction;

C_t : headloss coefficient due to transition;

C_{uc} : cost of upstream cofferdam;

C' : the orifice discharge coefficient through the sluiceways;

D : median size of a particle;

D_f : maximum diameter of objects entering the rackbars;

D_m : maximum possible size of material to be settled in the settling basin;

D_p : diameter of the flushing pipe;

D_r: diameter of the riprap;

d : depth of sluiceways;

d_{gwt} : distance from the soil surface to the ground water table;

E_{3s} : energy level at the riprap section at the downstream of the spillway;

E_{3sl} : energy level at the riprap section at the downstream of the sluiceways;

El_1 : Bed elevation where the pipe connects to river;

El_2 : bed elevation at the end of the settling basin;

E_u : upstream energy level;

e : eccentricity;

FS_o : factor of safety against overturning;

FS_s : factor of safety against sliding;

FS_{ss} : factor of safety against shear and sliding;

FS_u : factor of safety against uplift;

F_d : earthquake force;

F_h : hydrostatic force;

F_r : Froude number;

F_s : lateral active earth pressure;

F_u : uplift force;

F_{uh} : hydrostatic force acting on the subsurface portion of the spillway due to seepage;

F_w : upstream dynamic force due to earthquake;

f : freeboard;

f_{cf} : friction coefficient between concrete and foundation;

f_p : Darcy-Weisbach friction coefficient for the flushing pipe;

f^*: elevation difference between the water surface elevation and the crest elevation of the levee;

G : crest width of the cofferdam;

g : gravitational acceleration;

H : water depth above the crest of the spillway;

H_0 : total head above the crest of the spillway;

H_d : horizontal inclination of outer layers of downstream cofferdam;

H_e: existing total head over the spillway other than the design total head;

H_{net} : net total head between the upstream of the spillway and the riprap section;

H_{sp}: height of sheet piling;

H_u : horizontal inclination of outer layers of upstream cofferdam;

H_x : the elevation at point x relative to a datum;

h : water depth at the upstream of the spillway;

h_a : velocity head above the crest of the spillway;

h_d: elevation difference between the upstream energy grade line and the downstream (riprap section) water level;

h_{r_min} : minimum riprap thickness to be laid;

I : moment of inertia of the spillway base;

K : an orifice coefficient;

K_1 : bed elevation at the beginning of the main irrigation canal;

K_{100} : upstream water surface elevation for the flood discharge, Q_{100};

K_{50} : upstream water surface elevation for the flood discharge, Q_{50};

K_{25} : upstream water surface elevation for the flood discharge, Q_{25};

K_{10} : upstream water surface elevation for the flood discharge, Q_{10};

K_5 : upstream water surface elevation for the flood discharge, Q_5;

K_a :active earth pressure coefficient;

K_{ab} : contraction coefficient due to abutments;

K_b : water surface elevation at section-b of diversion canal;

K_{bs} : foundation elevation of the stilling basin;

K_c : water surface elevation over the step at the end of the diversion canal;

K_d : water surface elevation at the riprap section;

K_{d100} : water surface elevation at the riprap section for the flood discharge, Q_{100};

K_{d50} : water surface elevation at the riprap section for the flood discharge, Q_{50};

K_{d25} : water surface elevation at the riprap section for the flood discharge, Q_{25};

K_{d10} : water surface elevation at the riprap section for the flood discharge, Q_{10};

K_{d5} : water surface elevation at the riprap section for the flood discharge, Q_5;

K_p : contraction coefficient due to piers;

K_r : bottom elevation at the riprap section;

K_s : crest elevation of the spillway;

K_{sl} : crest elevation of the sluicegates;

$K_{st\,:}$ thalweg elevation at the entrance of the intake (spillway axis);

K_{sw} : crest elevation of the sidewalls;

K_{ta} : minimum river bed elevation at section-a of the diversion canal;

K_{tb} : minimum river bed elevation at section-b of the diversion canal;

K_u : upstream water surface elevation;

K_{us} : bottom elevation of the stilling basin

K_v : Von Karman constant;

K_w: water surface elevation at a cross-section;

K_{wi} : water surface elevation in front of the intake;

k_h : horizontal seismic earthquake coefficient;

k_s : the equivalent sand roughness;

k_v : vertical seismic earthquake coefficient;

L : crest length of the spillway;

L_c : length of curvature at the intake;

L_{cr} : creep length;

L_d : length of the riprap section;

L_{dc} : length of diversion canal;

L_{d_min} : minimum riprap length;

L_e: width of sluiceway;

L_p : length of flushing pipe;

L_s : length of the settling basin;

L_{ub} : length of upstream blanket;

L_x : the creep length up to point x;

L_T : length of the valley at the crest elevation of the spillway;

L_t : length of transition;

M : the net moment about the centerline of the base of the spillway body;

n_{conc} : Manning's roughness coefficient for the concrete lined canal;

n_p : the number of bridge piers at the entrance of main irrigation canal;

n_{pi} : the number of bridge piers at the entrance of intake;

n_{pipe} : Manning's roughness coefficient for the flushing pipe;

n_{ps} : the number of bridge piers above the spillway;

n_{river} : Manning's roughness coefficient for the river;

n_{row} : number of the rows that the stones should be laid over;

n_{sl} : number of sluiceways;

P : height of the spillway;

p_a : lateral active earth pressure;

Q : discharge;

Q_{100} : flood discharge having a return period of 100 years;

Q_{50} : flood discharge having a return period of 50 years;

Q_{25} : flood discharge having a return period of 25 years;

Q_{10} : flood discharge having a return period of 10 years;

Q_5 : flood discharge having a return period of 5 years;

Q_i : irrigation discharge;

Q_s : discharge over the spillway;

Q_{sl} : discharge through the sluiceways;

R : hydraulic radius;

R_c : radius of curvature;

r : is the sediment removal ratio;

S_o: mean river bed slope;

S_{os} : bed slope of settling basin;

S_{odc} : mean slope of the diversion canal;

$\overline{S_{fs}}$: average friction slope;

t_p : the thickness of one pier at the entrance of main irrigation canal;

t_{pi} : the thickness of one pier at the entrance of the intake;

t_{ps}: thickness of one pier over the spillway;

t_{sb} : thickness of stilling basin;

t_{sl} : thickness of one pier between the sluiceways;

t_{slab} : base slab thickness of the sidewall;

t_{sw} : thickness of the sidewall;

u : average flow velocity at a cross-section;

u_{5max} : maximum allowable flow velocity at the end of settling basin;

u_s : average flow velocity in the settling basin;

u_x : the uplift pressure head;

u_* : shear velocity;

u_{*c} : critical shear velocity which initiates sediment motion at the bed;

V_u : vertical inclination of outer layers of downstream cofferdam;

V_d : vertical inclination of outer layers of upstream cofferdam;

V_{sb1} : volume of USBR type 1 stilling basin;

V_{sb2} : volume of USBR type 2 stilling basin;

V_{sb3} : volume of USBR type 3 stilling basin;

V_{sb4} : volume of USBR type 4 stilling basin;

W : dead loads;

W_f : fall velocity of a particle;

w : height of the downstream cofferdam;

w_r : river width;

y : water depth at a cross-section;

$y_{2,max}$: maximum value of the sequent depths of hydraulic jumps;

y_{cs} : critical water depth at the toe of the spillway;

y_{csl} : critical water depth at the toe of the sluiceways;

y_i : water depth in front of the entrance of the intake;

y_o : normal water depth;

y_s : depth of flow in the settling basin ;

z : height of upstream cofferdam;

z_h : horizontal inclination of the trapezoidal canal;

Δ : step height at the end of diversion canal;

Δ_s : end sill height of the spillway's stilling basin;

Δ_{sd} : downward step at the entrance of the settling basin;

Δ_{sl} : end sill height of the sluiceways stilling basin;

Δ_{su} : height of the upward sill at the end of the settling basin;

Δ_u : upward sill at the beginning of the intake;

ΔE_{3s} : headloss due to the hydraulic jump at the spillway downstream;

ΔE_{3sl} : headloss due to the hydraulic jump at the sluiceways downstream;

ΔH_e : the minor loss above an upward sill;

ΔH_{ei} : the minor loss above at the submerged curtain wall located at the entrance of the intake;

ΔH_{es} : the minor loss above the downward sill, Δ_{sd} ;

ΔH_{g1} : minor loss due to gates;

ΔH_i : minor loss above the upward sill, Δ_u ;

ΔH_s : frictional headloss through the settling basin;

ΔH_t : minor loss through the transition;

ΔH_{tr} : minor loss at the thrashracks;

ΣH : total net horizontal force acting on the overall structure;

ΣL_{ucre} : the total creep length;

ΣL_h : the total creep length in the horizontal direction.

ΣL_v : the total creep length in the vertical direction;

ΣM_o : total overturning moments;

ΣM_r : total resisting moments;

ΣV : total net vertical force acting on the overall structure;

$\Sigma\Delta x$: the length of the river along which water rise occurs;

ϕ : uplift reduction coefficient;

α : angle from the upstream face of the spillway to the vertical direction;

β : dimensionless velocity;

γ_{conc} : specific weight of concrete;

γ_w : specific weight of the water;

θ : angle of repose of the soil;

λ : a parameter as a function of dimensionless velocity, β;

ρ : density of water;

σ_{ac} : allowable compressive strength of concrete;

σ_{af} : allowable compressive strength of foundation;

σ : base pressure;

τ_o : shear stress through the pipe;

τ_{oc} : critical shear stress which initiates sediment motion at the bed;

τ_s : allowable shear stress in concrete.

CHAPTER 1

INTRODUCTION

Diversion weirs are one of the significant structures of water resources systems since their design and construction require comprehensive and detailed work in terms of several civil engineering aspects. Although the governing part of their design is related to hydraulic engineering, other civil engineering divisions, such as structural engineering, geotechnical engineering, and environmental engineering are also incorporated in the design process. Another difficulty in the design of a diversion weir is due to the fact that it has many structural components which are considered for different and special purposes. Each of these components are interrelated to each other in terms of the data used in their design. Therefore, this situation entails an organization of the data throughout the method of design.

Hydraulic design of a diversion weir consists of many open-channel hydraulics concepts to be implemented. However, this causes a wide range of hydraulic theory to be applied in order to design all the structural components. In addition to this difficulty, diversion weir design also depends on many number of variables which affect the design in different ways resulting in various alternatives. This is the typical characteristic of a water resources engineering problem that forces the designer to choose the best design through iterative type of computational procedure. However, an iterative approach requires great amount of computational work to be performed which is very difficult without the utilization of computer programs. For those reasons, computer softwares play an important role in the design of hydraulic structures, such as diversion weirs. Especially, with the improvement in the computer sciences, better designs are done by using sophisticated computer packages.

There are many computer programs that deal with different aspects of hydraulics and other engineering disciplines. However, most of these programs are developed for general purposes to attract greater number of customers due to economical considerations by the developers of the packages. In this manner, a diversion weir design needs different computer programs in order to perform the calculations corresponding to each of its design problem. Although this is possible by using different packages in cooperation, by this way, the efficiency of the designer decreases in terms of the time he spends for the computations. This cumbersome process between one program to other also increases the risk of making mistakes.

Among the different types, diversion weirs with sidewise intakes are widely used in Turkey in plain rivers to divert water for irrigation purposes. By considering this fact, two computer programs have been developed to fulfill the requirement of a computer aided design for the diversion weirs with sidewise intakes ((Yanmaz and Cihangir, 1996), (Yanmaz and Özaydın, 2000)). However, these programs were written for DOS operating system which does not give a design engineer enough flexibility throughout the design of a diversion weir. The aim of the current study is to develop a specialized software in order to deal with the overall design of diversion weirs in context of hydraulic aspects by extending the capabilities of these existing computer programs. More specifically, the present study aimed to satisfy the needs by combining the hydraulic computations of the components of the diversion weirs in a single computer program. A computer program named WINDWEIR has been developed for this purpose. The program has a very flexible visual interface working on the Windows operating system, which enhances the efficiency of the user, resulting in better designs. In this study, it is intended to form a computer-aided basis for an integrated design by assembling all the required aspects in a single computer package.

This study is composed of the following chapters: Chapter 1 presents the general information about the objective of the study. In Chapter 2, the detailed information about the diversion weirs are introduced in parallel with the definitions of the corresponding theories of hydraulics which establish a foundation for the design of the diversion weirs. Hydraulic design of diversion weirs in a procedural way is explained in Chapter 3 which constitutes the core of this study. In Chapter 4, the implementations of the algorithms presented in Chapter 3 by WINDWEIR are clarified. An application of the program is given in Chapter 5. Finally, the conclusions and the recommendations regarding this study are presented in Chapter 6. Appendix A presents a user's manual for WINDWEIR whereas the source code of the program is given in Appendix B.

CHAPTER 2

DIVERSION WEIRS

2.1 Definition of Diversion Weirs

A diversion weir is a structure built across a river to raise water elevation up to a specified level and to divert the water in a specified orientation for different purposes, such as irrigation, hydropower generation, flood control, etc. There are some important criteria that should always be satisfied in the design of diversion weirs irrespective of type. These criteria are listed below (Yanmaz, 2001):

1. The desired amount of water should be diverted for most of the time.
2. The sediment grains in water should not be allowed to enter the water intake. However, no matter how perfect the design is, some sediment will always exist in the diverted water. Therefore, an ideal design should aim at limiting the amount of entrainment of especially coarse sediment into the intake.
3. Headlosses in the intake should be minimized in order to have a low spillway.
4. Accumulated objects in front of the intake should be easily flushed downstream.
5. The flow velocity should be controlled in order to protect the river bed from the erosion and to protect the related structures from scouring.
6. Water level fluctuations in front of the intake should be decreased.

As it is seen from the above criteria, one of the most important aspects, that should be considered in the design is the prevention of entrainment of sediment into intakes. Especially in rivers carrying large sediment loads, this is an important problem that should be solved.

2.2 Classification of Diversion Weirs

Diversion weirs can be classified according to various criteria (Yanmaz, 2001). These classifications are presented in the following subsections.

2.2.1 Classification According to the Magnitude of Flood Discharge

In Turkey, diversion weirs are designed to withstand a flood discharge having a return period of 100 years, Q_{100}. Therefore, diversion weirs can be classified according to the magnitude of Q_{100} as follows:

i. Small diversion weir ($Q_{100} < 100$ m^3/s)
ii. Medium diversion weir ($100 \leq Q_{100} \leq 500$ m^3/s)
iii. Large diversion weir ($Q_{100} > 500$ m^3/s)

2.2.2 Classification According to Structural Design

i. Diversion weir with spillway : Raising of the water elevation is provided by constructing a spillway across the river (see Figure 2.1). This study concentrates basically on this type of diversion since most of the diversion weirs in Turkey are designed for this type.

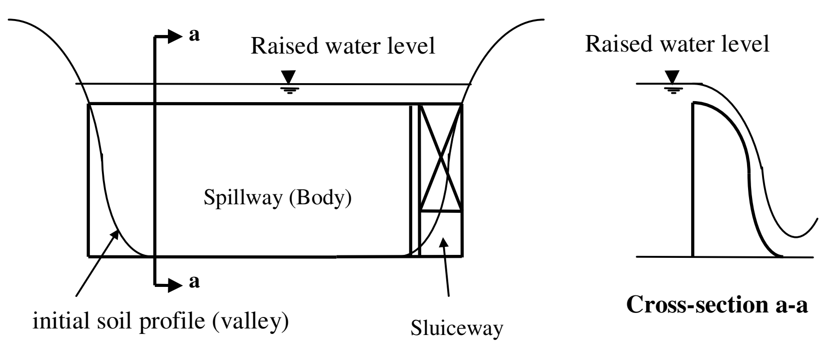


Figure 2.1. Sketch of a diversion weir with spillway.

ii. Gated diversion weir : Raising of the water surface elevation is provided by lowering the gates between the piers constructed across the river as shown in Figure 2.2. This type of diversion weirs are capable of controlling the upstream water level in the case of discharge fluctuations. Also by the use of gates, flushing of the accumulated sediment in the upstream part of the structure is easier. However, continuous operation of gates under high dynamic impact may cause some operational problems, which can be seen as a disadvantage of a gated diversion weir. Çulcu (2000) and Arslan (1996) can be referred for a detailed survey on gated diversion weirs.

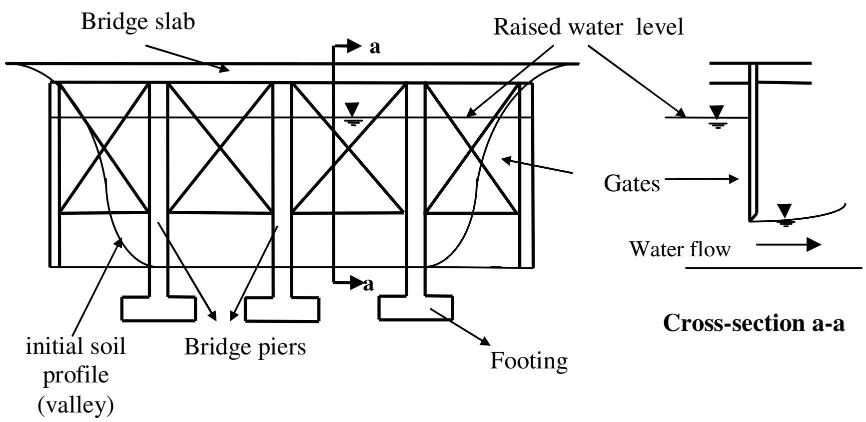


Figure 2.2. Sketch of a gated diversion weir.

iii. Mixed type of diversion weirs : This type of diversion weir is composed of the combination of spillway and gated weir.

2.2.3 Classification According to Orientation of Intake

i. Diversion weir with sidewise (lateral) intake : This type of intake is the most commonly used type among the others. This is generally suitable for plain rivers where the sediment concentration in the vertical direction is close to uniform (see Figure 2.3). The present study is based on the computer assisted hydraulic design of this type.

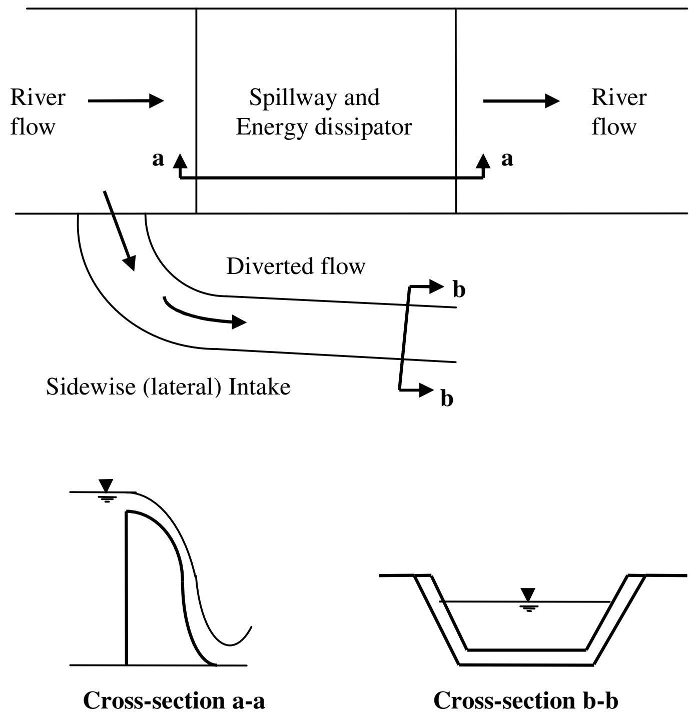


Figure 2.3. Sketch of a diversion weir with sidewise intake.

ii. Diversion weir with frontal intake : In this type of diversion weirs, the intake structure is placed on top of the sluiceway to divert water with low sediment concentration. A definition sketch shown in Figure 2.4 in which Q is the total river flow and Q_i is the diverted flow. With greater dimension of the sluiceway better flow conditions can be facilitated. Normally, some sediment is deposited in front of the sluiceway, but this sediment can easily be flushed by water with the regular operation of sluice gates and by choosing a proper bottom slope for the sluiceway, i.e. a recommended bottom slope is about 2.5% ((Şendil, 1962), (Garbrecht, 1963), (Yanmaz, 2001)). Since proper sediment handling can be established by frontal intakes, this type of structure is best suited to steep sloped rivers where sediment handling is a more important problem that should be solved.

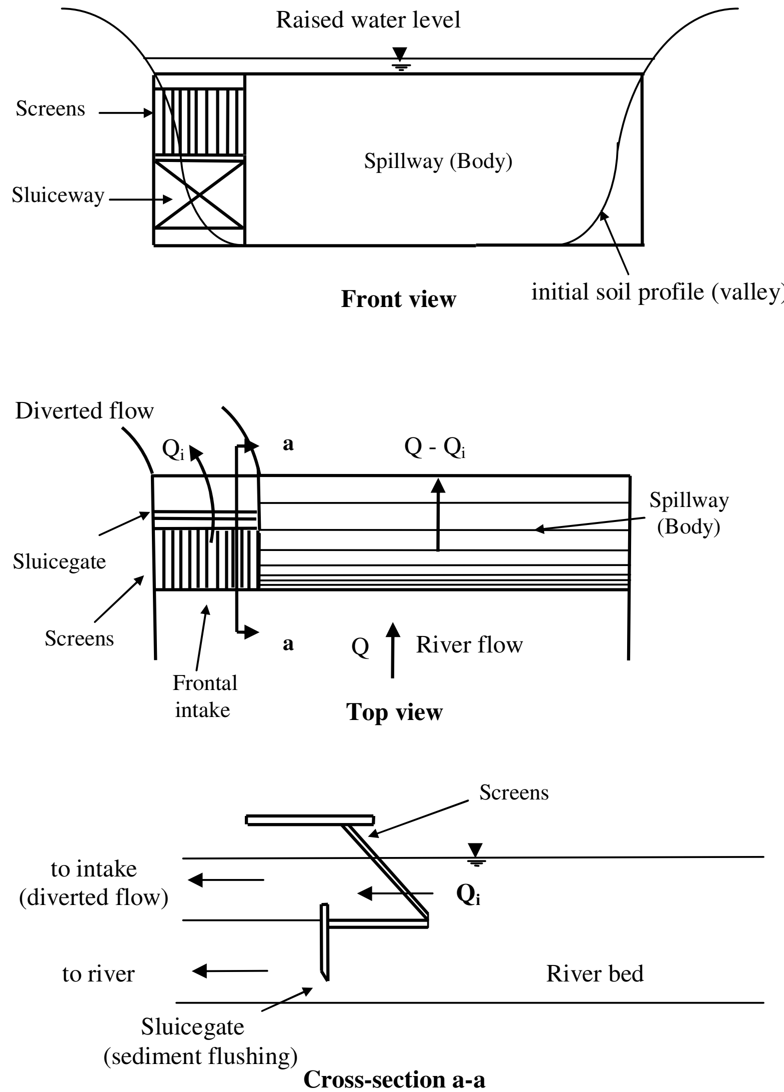
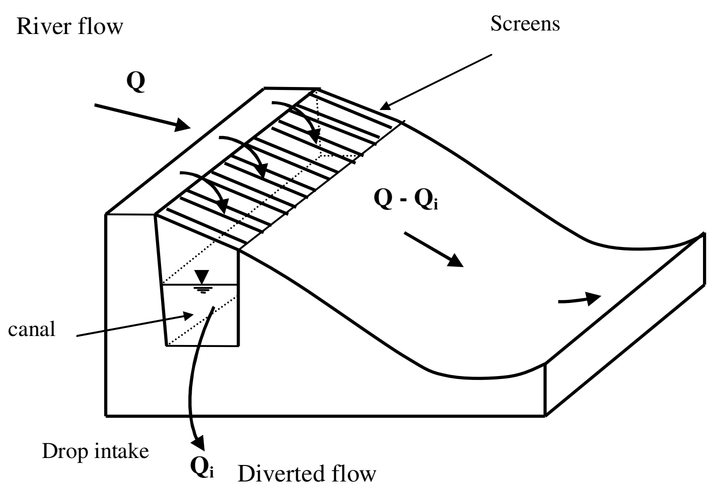
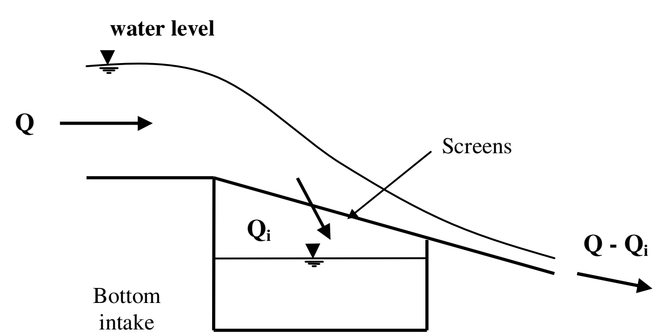


Figure 2.4. Sketch of a diversion weir with frontal intake.

iii. Diversion weir with drop (bottom) intake : This type of intakes divert the water from the crest of a spillway which is composed of screens as shown in Figure 2.5. Water is taken into a drop structure while it is flowing over the crest. This structure is best suited for very steep sloped mountainous rivers where sediment deposition is a very important problem to handle. With a sidewise intake, this problem is very difficult and uneconomic to overcome since a large settling basin is required under such conditions. In addition, some other structural components may be needed to handle the sediment problem. Therefore, if the bed slope of the river is greater than 5%, a drop type of intake is recommended. However, still some important precautions are needed in order to overcome the sediment which falls into the drop. For a more detailed information about diversion weirs with drop intake, Çeçen (1962) is to be referred.



Isometric view



Side view

Figure 2.5. Sketch of a diversion weir with bottom intake.

2.3 Determination of the Location and Type of a Diversion Weir

Purpose of the diversion weir, topography, soil conditions, orientation of the intake, sediment transportation and river morphology plays important role in determination of the location and the type of a diversion weir. For example, if a diversion weir is planned for irrigation purposes, generally the location is determined according to the location and the topography of the irrigation area. In a similar way, if a diversion weir is to be constructed to form a by-pass channel to protect an important hydraulic structure from excessive flow, then the river location where the structure is to be built is of importance.

Generally, in designing a diversion weir, the structure is desired to be built on a narrow section of the river in order to minimize the size and the cost of the structure. However, if upstream water level rises too much then big uplift forces due to excessive seepage increases the size of the structure which leads to higher construction, maintenance, and operation costs. Therefore, in general, for narrow valleys gated diversion weirs are recommended, while in wide valleys diversion weirs with spillway should be desired. Although above recommendations are important, in general, a final decision of the diversion weir type should be obtained after making some economical and hydraulic analyses iteratively.

In the design of diversion weirs, which are planned especially for irrigation purposes, one of the most important issue that should be considered is sediment transportation. For irrigation purposes, the main aim is to divert clean water from the river. Construction of the structure effects the flow conditions of the river which causes changes in the river morphology, such as erosion, deposition etc. By considering these effects, it can be concluded that gated diversion weirs are more suitable in rivers carrying large amounts of sediment loads, so that sediment can be transported by the proper operation of the gates.

Another important issue is the flow conditions at bends. In Figure 2.6 flow conditions in a river bend are shown. Bends cause secondary flows which in turn cause sediment deposition in the inner edge of the bend while erosion takes place in the outer edge due to the effects of centrifugal force. The effect of secondary current is strongest at about two times the river width downstream from the point where the river width downstream from the point where the river axis intersects the outer bank. Therefore, it would be more favorable to construct the water intake structure at this location (see Figure 2.6). This advantage of the bends should also be considered in determination of the diversion weir location. Furthermore, it may be a good decision to generate an artificial bend in the lack of a natural bend in order to access this advantage of bends. For a more detailed study regarding the hydraulics of flow at the bends, studies of Çulcu (2000) and Özbek (1989) are also to be examined.

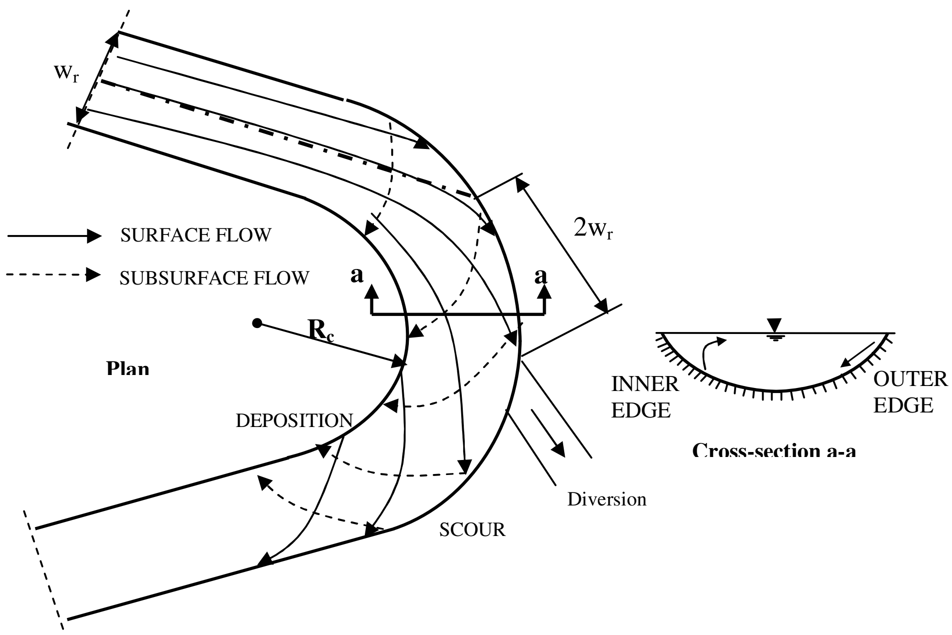


Figure 2.6. Flow at bends (Yanmaz, 2001).

Regarding the secondary flows at the bends, Habermaas (1955) has performed some model studies under constant channel bed slope and resulted in the solution that the effect of secondary flows can be diminished by the existence of an enlarged flow section in the upstream of the intake. Figure 2.7 shows the several orientations of intake regarding the sediment control facilities as the results of Habermaas's studies.

In the light of the above discussions it can be stated that there exist many alternatives in the design of diversion weirs. Most of the time, the best solution is found as a result of iterative studies. Therefore, all the criteria on the determination of location and type of diversion weirs are to be examined in a detailed manner and the most reasonable solution is achieved by making joint hydraulic, structural, and economical analyses.

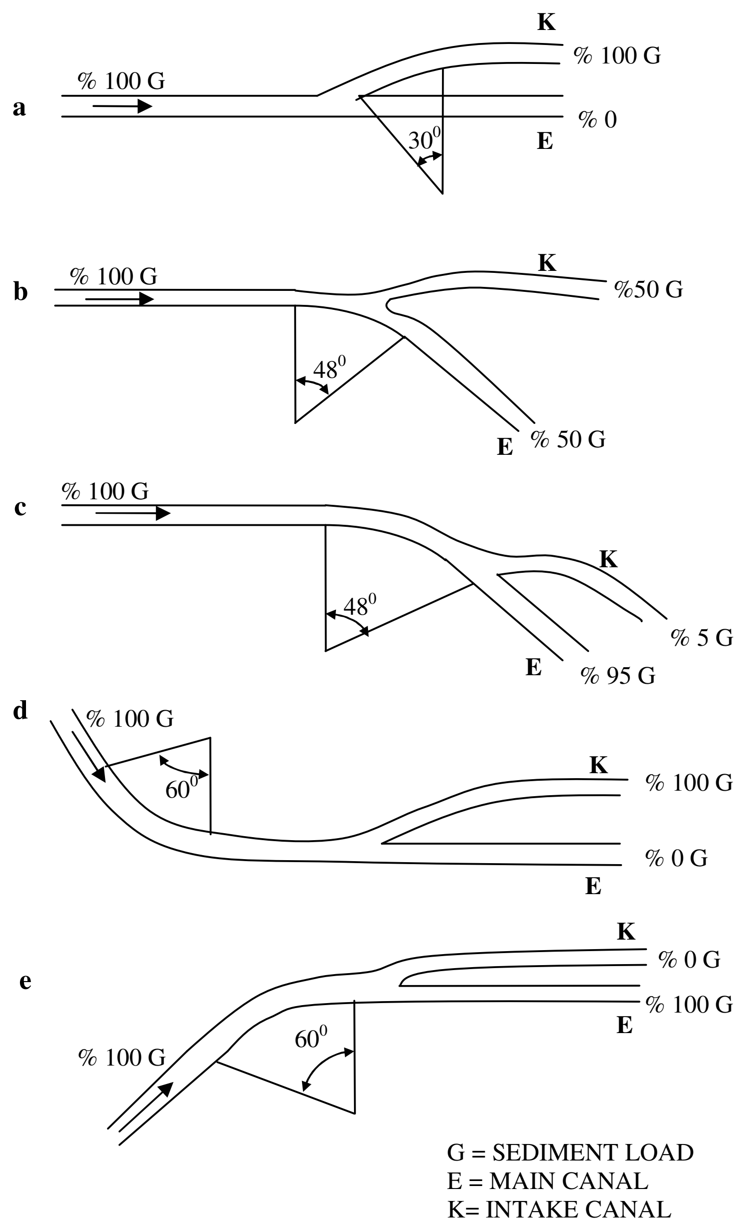


Figure 2.7. Several orientations of intake (Habermaas, 1955).

2.4 Structural Components of Diversion Weirs with Sidewise Intakes

The general layout of a diversion weir with a sidewise intake is shown in Figure 2.8. Structural components are described in the following subsections.

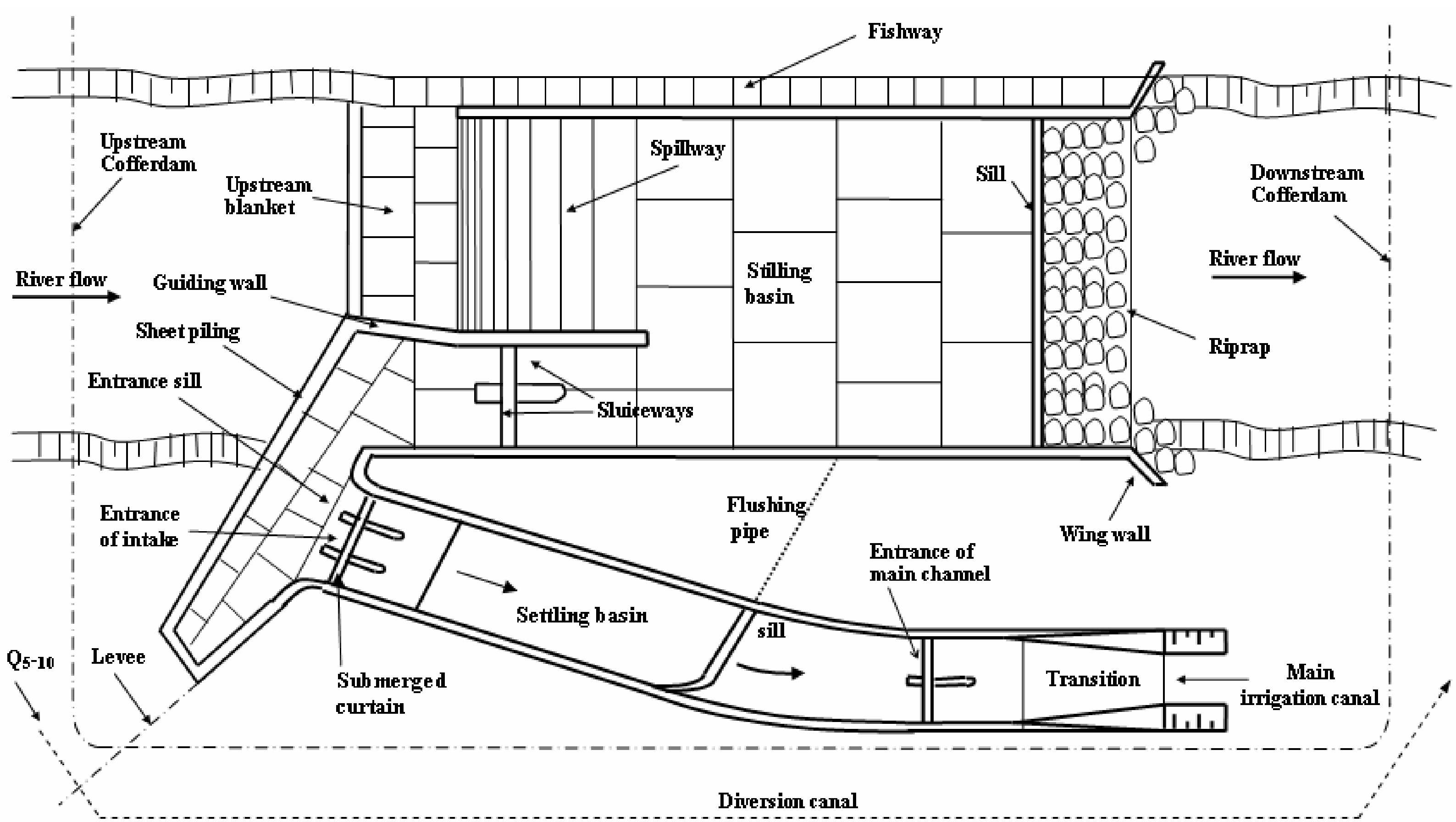


Figure 2.8. Plan view of a typical diversion weir with a right sidewise intake.

2.4.1 Spillway

Spillway is the main structural component of a diversion weir. The most important function of the diversion weir is fulfilled by the spillway by raising the upstream water level. In this way, water is diverted to the intake structure at a specified elevation. Sometimes in addition to the spillway body, a bridge is constructed over the spillway for service facilities. In Figure 2.9 longitudinal profile of a typical spillway can be seen.

2.4.2 Energy Dissipating Basin (Stilling Basin)

Stilling basin is the structure which is built at the toe of the spillway to prevent the scouring of river bed. It is made of concrete blocks of compressive strength 250 kgf/cm^2 placed in 5 m lengths approximately. The thickness of these blocks are determined according to the safety of the slab against uplift. Longitudinal profile of a typical stilling basin is also shown in Figure 2.9.

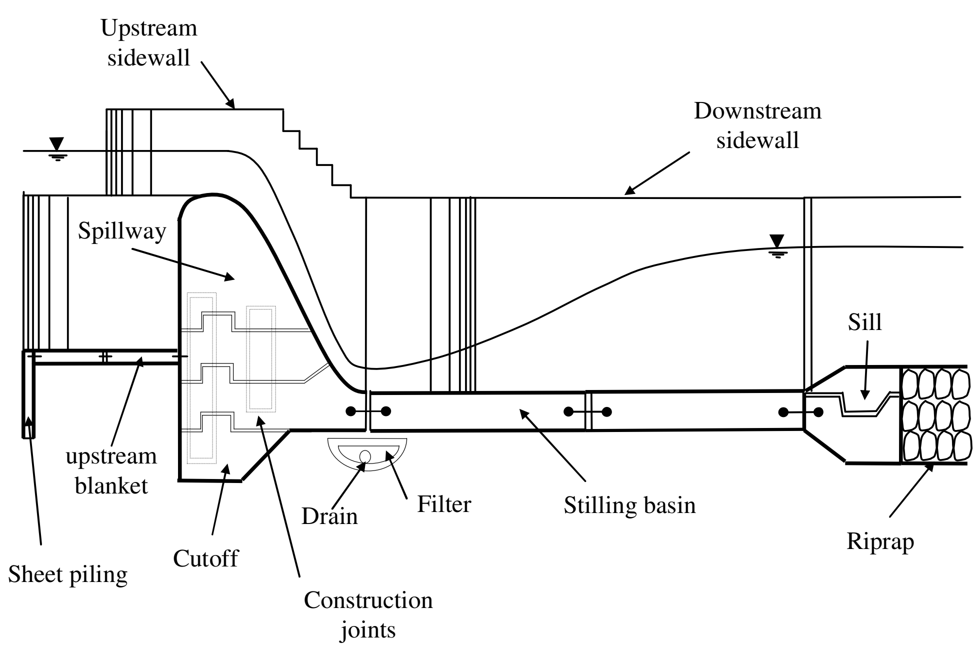


Figure 2.9. Longitudinal profile of a typical spillway and stilling basin.

2.4.3 Sluiceway

It is an important structural component of a diversion weir, which flushes the sediment accumulated in front of the intake. Sluiceways have vertical lift gates called as sluicegates. In front of the sluicegates, usually a submerged curtain is constructed. Deposited sediment is flushed downstream to the river through the sluiceway. When sediment is deposited up to a certain level, sluicegates are opened and deposited sediment is discharged to the river by the help of the high flow velocities occurred through sluicegates. Sluiceways are designed to have a bottom slope of about 1/20 to 1/50 in order to facilitate flushing of the sediment to river (see Figure 2.10 for the longitudinal profile of a typical sluiceway and stilling basin).

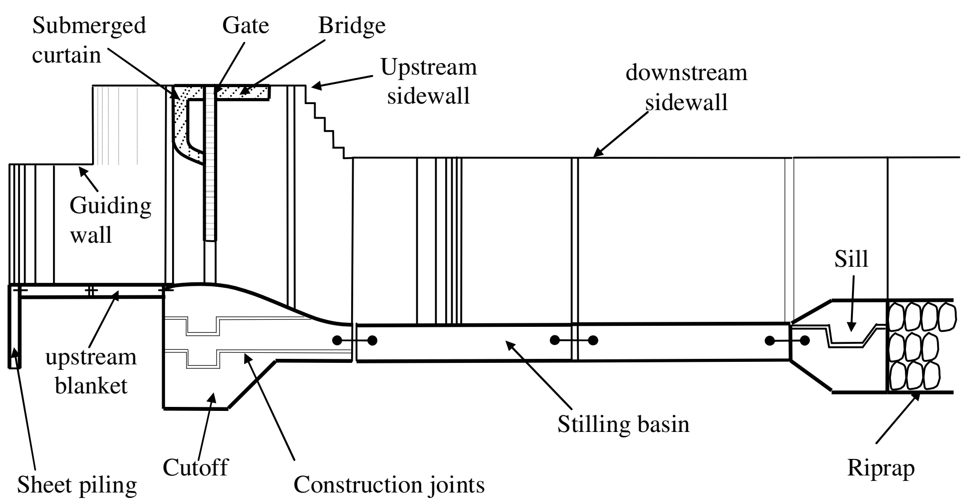


Figure 2.10. Longitudinal profile of a typical sluiceway and stilling basin.

2.4.4 Guiding Wall

In order to help sediment handling, a guiding wall is placed between the spillway and sluiceway to deflect the sediment towards the sluiceway. This wall is called guiding wall. Its orientation is an important issue and can be determined through hydraulic model studies. According to the studies made by Özbek (1989), the following results were obtained.

- Guiding wall length is an important factor in the design of diversion weirs with sidewise intakes. It is seen that for the same amount of sediment deposition, when small amount of water is discharged to the intake, shorter guiding wall is needed, whereas longer guiding wall is necessary when large amount of water is to be discharged to the intake. As a result it is stated that; a guiding wall should be constructed in such a length that it should cover the entrance of the water intake.

- Angle between the flow direction and the guiding wall should be about $15^0 \sim 20^0$.

- For a better sediment handling, flow through the sluiceway should not be in submerged conditions.

- In order to achieve a well sediment flushing, higher and longer guiding walls should be preferred. Although high and long guiding wall increases minor headlosses, it gives better results from sediment handling point of view.

- Sluicegates should be closed for a better deflection of sediment to the front of the sluiceway.

2.4.5 Sidewalls

Sidewalls are the retaining walls which confine the river flow. Both gravity and cantilever type reinforced concrete retaining walls can be used for sidewalls. Usually, cantilever type is more preferable due to economical reasons. Plan view and cross-section of typical sidewalls are shown below in Figure 2.11.

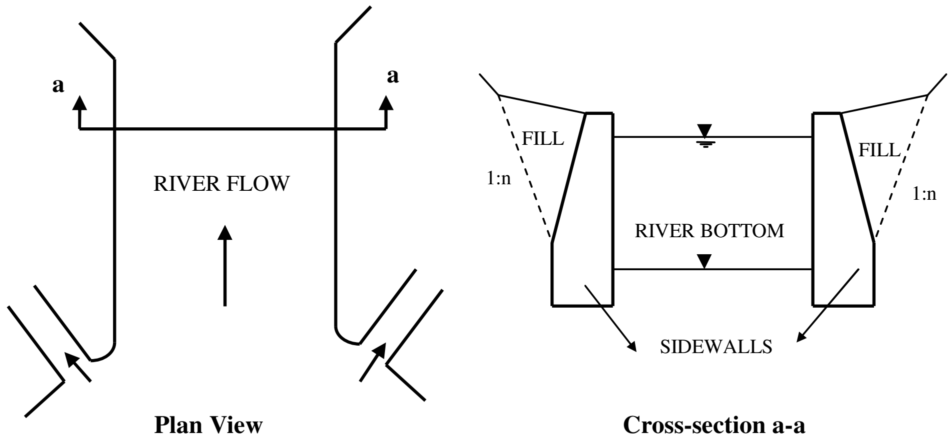


Figure 2.11. Plan view and cross-section of sidewalls (Yanmaz, 2001).

2.4.6 Upstream Blanket

They are formed of concrete blocks of 4*4 m^2 in dimensions. An approximate thickness of 30 cm is used as the thickness of these blocks. The main reason of the construction of these blocks is to retard the seepage path. Also a sheet pile is driven at the end of the upstream blanket to further increase the seepage path. By the construction of sheet pile and upstream blanket, uplift forces decrease such that the desired level of safety against uplift is achieved. In Figures 2.8, 2.9 and 2.10, upstream blanket and sheet pile are shown.

2.4.7 Riprap Section

At the end of the stilling basin, large ripraps are laid at least 75 cm thick and 10 m long in order to protect the river bed.

2.4.8 Fish passage

A fish passage is the component which consists of successive pools to facilitate the passage of fish from one side to other side of the structure. This structure has secondary importance in the design of diversion weirs, because it is required to be built at sites where fishing is of economic importance.

2.4.9 Raft passage

Similar to the fish passage, a raft passage is constructed for log transportation. It is important at sites where log transportation is important as in the case of Scandinavian countries.

2.4.10 Intake

Intake is an important structural component of a diversion weir because the water is taken from the river through this component. The required discharge taken from the river is transmitted to the main channel. The amount of discharge taken is controlled by the proper opening of the gates installed at the entrance of the intake. There are some structural components that compose the intake structure. Figure 2.12 shows the longitudinal profile of a typical intake and its components. These components are described below.

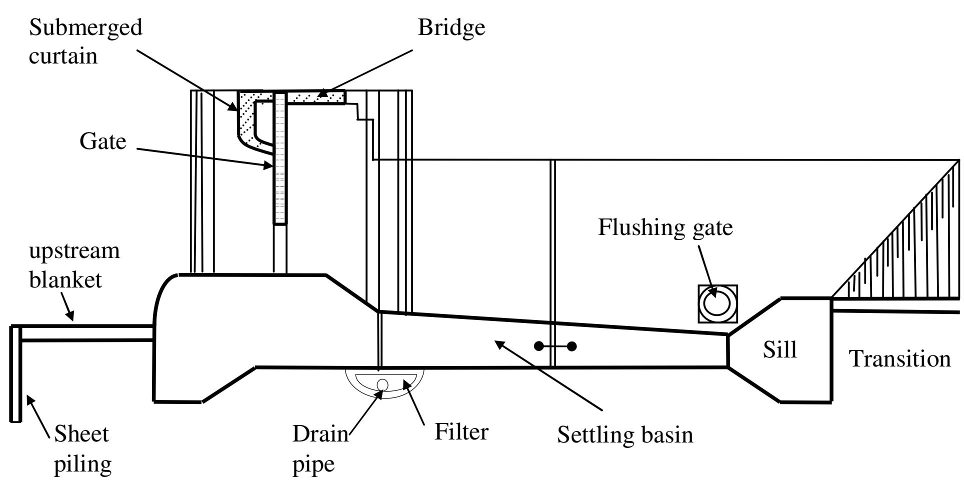


Figure 2.12. Longitudinal profile of an intake.

- Submerged Curtain : It is built within the flow section of water perpendicular to the flow direction and placed in front of the gates in order to prevent some floating objects, such as ice, logs, etc., to enter into the intake. A minimum of 50~60 cm depth from the top of the intake is recommended for the height of a submerged curtain.

- Screens : They are the racks placed in front of the gates to prevent the entrainment of floating objects and coarse sediment into the intake.

- Settling basin : It is the enlarged compartment of intake serving for further sediment handling purposes. The fine particles of sediment entering into intake are captured at the settling basin. Length of the settling basin is the main variable in capturing the sediment. Required length is calculated due to the settlement of sediment grains up to a specified size. Although a settling basin is usually a single large compartment with a rectangular cross-section, some settling basins may be composed of successive small compartments neighboring to each-other.

- Flushing pipe : The settled sediments deposited at the end of the settling basin should also be discharged to the river. Therefore, a flushing pipe is constructed at the end of settling basin which joins the river to flush the deposited sediment to the river. Flushing pipe is designed to operate in pressurized flow conditions. Therefore, when the required amount of sediment is deposited at the settling basin, the gates in front of the main canal is closed in order to achieve pressurized flow conditions in the flushing pipe. Therefore, irrigation is stopped while the flushing pipe is in operation. However, in the case of settling basin having some compartments in series, some of the gates of the main canal are kept open to continue irrigation. A flushing pipe is a circular conduit whose diameter and slope are determined in order to achieve self-cleansing. A minimum diameter of 60 cm is recommended for the conduit (Yanmaz, 2001).

- Transition : It is the structural part of the intake that connects the rectangular settling basin to trapezoidal main irrigation canal. Bends are used in order to change the flow direction. There are different types of transitions, which can be seen in Figure 2.13. Straight Transition is widely used because of ease of its construction. However, higher headlosses occur through the straight transition. A Streamlined Transition is the best one because of its geometry that minimizes the headlosses, but its construction is difficult. In character, a Broken-Back type of transition is between straight transition and streamlined transition such that the headloss generated is smaller than a straight transition, but higher than a streamlined transition and its construction is more difficult than the straight transition but easier than the streamlined transition. The suitable type is chosen by concerning both constructional difficulties and hydraulics.

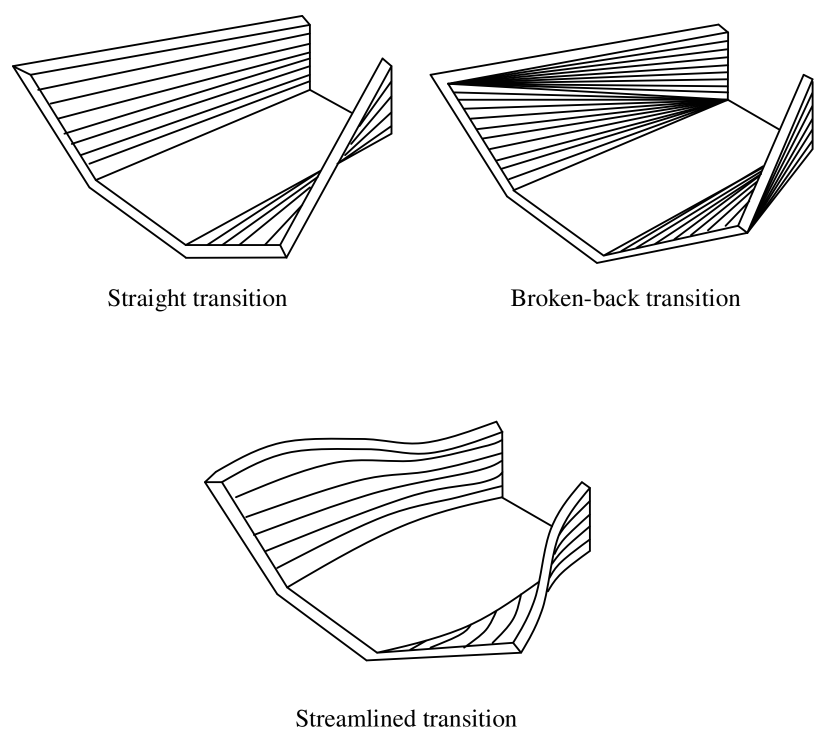


Figure 2.13. Types of transitions (Sungur, 1988).

At the entrance of the intake, an upward sill with a minimum height of 60 cm above the bottom of sluiceway is constructed such that the entrainment of the bed load into the intake is avoided. However, water striking to the sill may generate secondary flows causing some of the sediments to enter into the intake. Because of this possibility, sluiceway should be operated with care concerning this problem.

2.4.11 Some Appurtenant Structures

The construction of a diversion weir is similar to the construction of a small dam in various aspects. Therefore, in addition to the structural components of a diversion weir, some appurtenant structures are needed. These appurtenant structures are described below.

- Levees : They prevent the flooding of the environment because of the raised water at the upstream of the diversion weir.

- Cofferdams : A dry construction zone is provided by the construction of cofferdams in the upstream and downstream part of the construction zone. At the end of the construction period of the diversion weir, the cofferdams are demolished and river starts to flow in its original bed by passing through the diversion weir.

- Diversion Facility : River flow is diverted by a diversion canal usually having a capacity of flow with return periods of 5 or 10 years.

CHAPTER 3

HYDRAULIC DESIGN OF DIVERSION WEIRS

3.1 Hydraulic Design of Diversion Weirs with Sidewise (lateral) Intakes

Design of a diversion weir is a complicated and tedious work, because all of the structural components of the diversion weir are designed separately but in cooperation such that design results of any component are inputs for the next component. Therefore, computations regarding all of these components should be carried out in a systematical procedure. The sequence of design computations are as follows:

- Water Surface Profile Computations
- Design of Structural Elements
    - Intake
    - Spillway
    - Sluiceways
    - Energy Dissipator
    - Sidewalls
    - Levees
    - Diversion Facility
        - Diversion Canal
        - Cofferdams
- Design of some appurtenant facilities
    - Riprap Design
    - Flushing Canal
- Seepage Analysis
- Stability Analysis

3.1.1 Water Surface Profile Computations

After the planning stage in which the location of the diversion weir is selected, the first step in the hydraulic design is water surface profile computations which are made along the river reach where the spillway and corresponding energy dissipator are constructed. This is a very important process, because the computations related to the structural components of the diversion weir depend mostly on the water surface elevations. Since the flow in a plain river is usually in sub-critical regime, the computational direction is from the downstream toward the upstream. Therefore, the downstream rating curve needs to be constructed in order to be used as a boundary condition for the hydraulic design.

For determining the downstream rating curve, firstly a flood frequency analysis for the annual series of the maximum discharges should be made to calculate the flood discharge values for various return periods. Downstream rating curve is plotted for the discharges for the return periods of 5, 10, 25, 50, and 100 years. Therefore, the values of Q_{100}, Q_{50}, Q_{25}, Q_{10}, and Q_5 are needed for hydraulic analysis and design computations. Although a diversion weir is designed for Q_{100}, it should also serve with a good hydraulic performance under smaller discharges, such as Q_{50}, Q_{25}, Q_{10}, and Q_5. Once these discharges are obtained, the water surface profile computations can be carried out using HEC-RAS (USACE, 1998) and BHSA (Yanmaz and Bulut, 2001) program packages, which will not be covered in this thesis.

3.1.2 Design of Structural Elements

After water surface profile computations are made, the next step in the design of a diversion weir is the determination of the dimensions of the structural components by considering hydraulic criteria. Each sequential component is dimensioned by making necessary hydraulic computations in a systematical order. In this section, hydraulic design of each component is explained.

3.1.2.1 Design of Intake

Design of structural elements starts with the design of intake. The main aim in the design of intake is to find the crest elevation of the overflow spillway. Starting from a known water elevation at the beginning of the main irrigation canal, all the headlosses through the intake are computed to find the corresponding water level at the entrance of the intake. This is the minimum water elevation which must occur at the entrance of the intake in order to provide the specified water level at the beginning of the irrigation canal for the required irrigation discharge. This elevation is incremented by approximately 10 cm accounting for water level fluctuations in front of the intake and further frictional losses through the intake. The resulting elevation is taken as the crest elevation of the overflow spillway. In this section, the headlosses through the intake are examined to explain the design of intake starting from the irrigation canal to the entrance of the intake where crest elevation of spillway is determined. Figure 3.1 shows the plan view and profile of intake indicating the headlosses that should be considered. All the following computations are explained with reference to Figure 3.1.

The required discharge taken to the intake is controlled by the proper operation of the gates. Although Parshall flumes can be used for discharge measurement purposes, they are not recommended for the reason that they cause considerable headloss in the intake. Instead of using Parshall flumes, appropriate use of gates at the entrance can enable the measurement of discharge.

Since the flow in the intake is in sub-critical regime, the boundary condition to be used in headloss computations is the water level at the beginning of the main irrigation canal which is section-1 in Figure 3.1. Therefore, calculations through the intake is performed from the downstream (section-1) to the upstream (section-9) by using the energy equation. Hydraulic computations are carried out to find water surface elevations at each section of the intake by taking into account the related headlosses as follows:

- Cross-section-1: The bed elevation, K_1, at the beginning of the main irrigation canal is an input variable, which is obtained as a result of application of the layout of the irrigation project on a physical map. The main irrigation canal has a trapezoidal

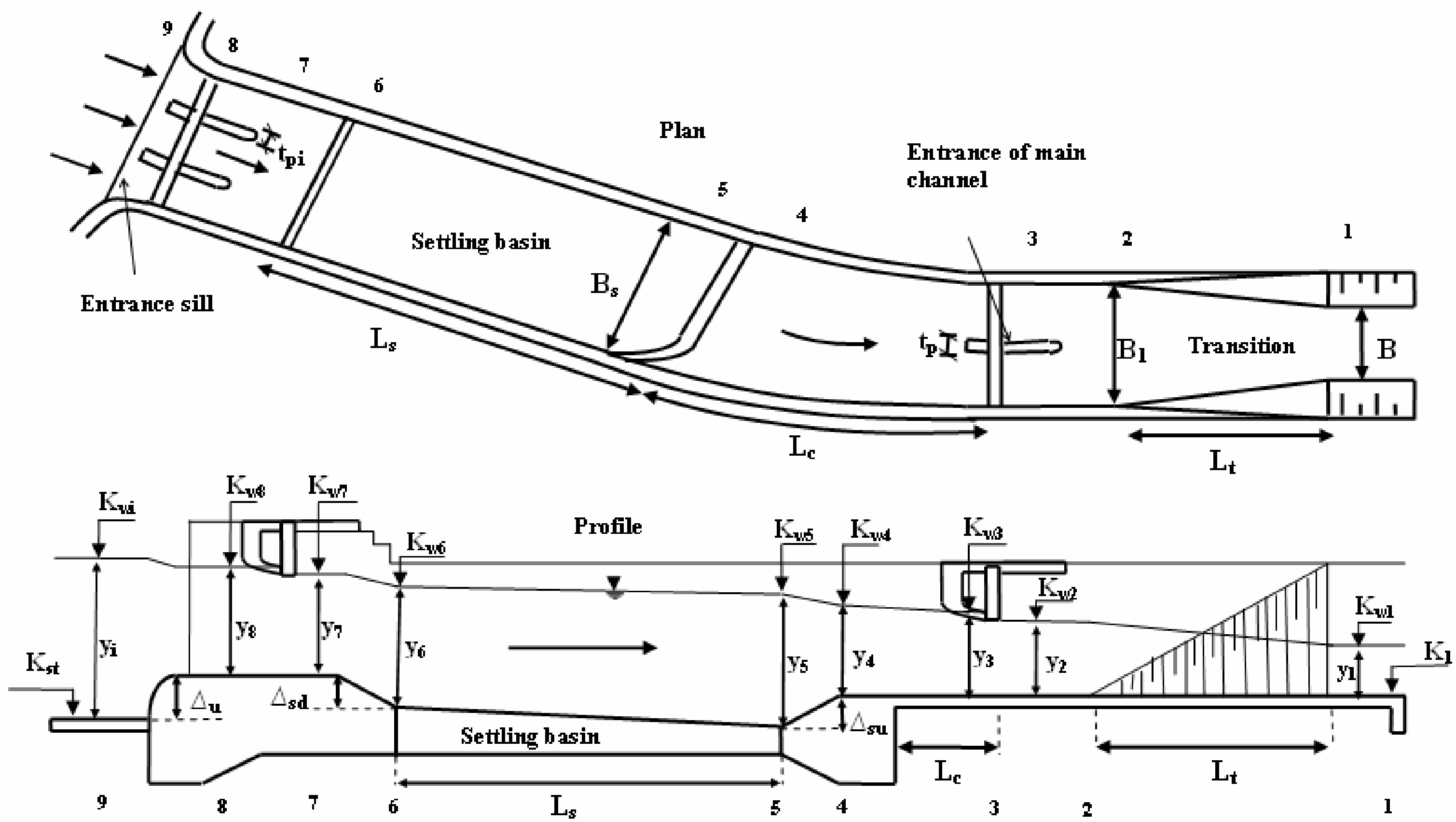


Figure 3.1. Plan and profile of intake.

cross-section having side slopes of 1V:1.5H. These side slopes are specifically recommended by taking into account both constructional difficulties and hydraulics performance (USBR, 1952). In addition to these input data, with the known irrigation discharge, Q_i, channel bottom width, B, Manning's roughness coefficient, and the channel bed slope, S_0, the normal depth, y_1 is computed by using Manning's equation. Thus, the water surface elevation at that section (section-1), K_{w1} is determined as follows:

$$K_{w1} = K_1 + y_1 \tag{3.1}$$

Calculated water depth, y_1, should be checked if it is greater than the critical depth of that section, y_{1c} such that $y_1 \geq 1.1y_{1c}$ in order to be convinced that the flow is in a stable sub-critical regime. The reason behind this check is to provide stable flow conditions such that in close vicinity of critical depth, the flow is said to be unstable.

- Cross-section-2: The entrance of the intake and settling basin are usually designed for rectangular cross-section, therefore, a transition connects the trapezoidal main irrigation canal to the intake. Various types of transitions, which are shown in Figure 2.13, can be used for that purpose. The headloss generated due to the transition is expressed as follows:

$$\Delta H_t = C_t \left(\frac{u_1^2 - u_2^2}{2g}\right) \tag{3.2}$$

where, ΔH_t : minor loss through the transition;
C_t : headloss coefficient due to transition;
u_1 : average flow velocity at section-1;
u_2 : average flow velocity at section-2;
g : gravitational acceleration.

Corresponding headloss coefficients due to different types of transitions can be obtained in Table 3.1. The flow depth at section-2 can be determined by applying the energy equation between section-1 and section-2 as follows:

$$y_1 + \frac{u_1^2}{2g} + C_t\left(\frac{u_1^2 - u_2^2}{2g}\right) = y_2 + \frac{u_2^2}{2g} \tag{3.3}$$

The water depth at section-2 can be expressed as $y_2=Q/(B_1u_2)$ where B_1 is the width of the rectangular canal at section-2 and submitted in Equation (3.3). Minimum value of 2B is proposed for the value of B_1 (Yanmaz and Cihangir, 1996). Then, Equation (3.3) can be solved for y_2. Condition of $u_1 \geq u_2$ should be satisfied for an inlet type of transition. If this condition is not fulfilled, the value of B_1 is incremented beyond 2B value successively until the required condition is obtained. The water level at this section, K_{w2} is found by applying the energy equation by the insertion of calculated u_2 value to Equation (3.4).

$$K_{w1} + \frac{u_1^2}{2g} + \Delta H_t = K_{w2} + \frac{u_2^2}{2g} \tag{3.4}$$

Table 3.1. Headloss coefficients due to transition types (Chow, 1959).

Type of Transition	C_t
Warped type	0.10
Cylinder-quadrant type	0.15
Simplified straight-line type	0.20
Straight-line type	0.30
Square-ended type	0.30+

The length of transition, L_t, can be determined from French (1987) :

$$L_t = 2.35(B_1 - B) + 1.65 z_h y_2 \tag{3.5}$$

where z_h=1.5 is the horizontal value of the side slopes of the main irrigation canal. Since the transition length is usually not long enough to cause considerable frictional loss, the headloss due to friction is usually eliminated in Equation (3.4). In case of a long transition, it should also be considered in the calculations.

- Cross-section-3 : As seen in Figure 3.2, a gate is placed at section-3 to regulate the flow and to prevent the entrainment of flow into the main irrigation canal during the flushing of the sediment accumulated in the settling basin. The gates are installed between a number of piers, thus, the flow velocity through the gate opening, u_3 can be determined by calculating the net flow area (see Figure 3.2).

$$u_3 = \frac{Q_i}{B_{3n} y_2} = K\sqrt{2g * \Delta H_{g1}} \tag{3.6}$$

where, B_{3n}, is the net width of the channel at section-3 which can be expressed as:

$$B_{3n} = B_1 - n_p t_p \tag{3.7}$$

where,

n_p : the number of piers;

t_p : the thickness of one pier;

K : an orifice coefficient which can be taken approximately as 0.65 (Sungur, 1988);

ΔH_{g1} : minor loss due to gates.

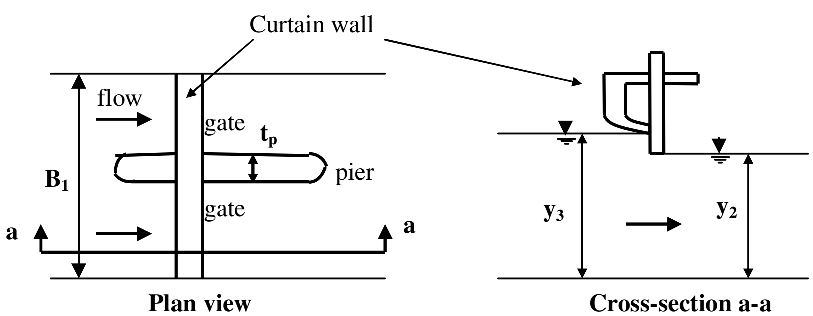


Figure 3.2. Definition sketch for section-3 and section-8.

By making proper substitutions the water depth, y_3 and water surface elevation, K_{w3} can be determined by applying the energy equations as follows:

$$y_3 + \frac{u_3^2}{2g} = y_2 + \frac{u_2^2}{2g} + \Delta H_{g1} \tag{3.8}$$

$$K_{w3} + \frac{u_3^2}{2g} = K_{w2} + \frac{u_2^2}{2g} + \Delta H_{g1} \tag{3.9}$$

- Cross-section-4 : The width of the settling basin is larger than the width at the entrance of the main irrigation canal. Therefore, a transition is provided between the entrance of the main irrigation canal (section-3) and the end of the settling basin (section-4) by a curvature having proper radius. The width of the rectangular settling basin, B_s is greater than the width at the entrance of the main irrigation canal, B_1 by a reasonable amount, e.g. 1~ 2 m in order to obtain the desired amount of sediment deposition in the settling basin as a result of the flow velocity. By considering the local site conditions, the designer should select appropriate values for the length, L_c, and the radius, r of the curvature. The minor loss generated by this curvature, $\Delta H_{c,}$ can be determined as a certain percentage of the difference of the velocity heads at the beginning and end of the curvature.

$$\Delta H_c = C_c\left(\frac{u_3^2 - u_4^2}{2g}\right) \tag{3.10}$$

where, u_3 and u_4 are flow velocities at sections 3 and 4, respectively. Minor loss coefficient C_c can be taken as 0.2 (Sungur, 1988). As in previous sections, application of energy equations between these sections gives the water depth, y_3 and water surface elevation, K_{w3} at the end of the settling basin as follows:

$$y_4 + \frac{u_4^2}{2g} + \Delta H_c = y_3 + \frac{u_3^2}{2g} \tag{3.11}$$

$$K_{w4} + \frac{u_4^{\ 2}}{2g} + \Delta H_c = K_{w3} + \frac{u_3^{\ 2}}{2g} \tag{3.12}$$

where, $u_4 = Q_i / (B_s y_4)$.

- Cross-section-5 : At the end of the settling basin, an upward sill is required in order to route the accumulated sediment in the settling basin to the flushing pipe. As well, the entrainment of the deposited sediments to the irrigation canal is avoided by the construction of this upward sill. An appropriate small velocity is required to facilitate the suspended particles to settle down. Maximum permissible velocity of 0.3 m/s is a reasonable value to be selected in the design (Yanmaz, 2001). By selecting the height of the upward sill, Δ_{su} in the range of 0.5 to 1.0 meter, the energy equation is applied as:

$$y_5 + \frac{u_5^{\ 2}}{2g} = \Delta_{su} + y_4 + \frac{u_4^{\ 2}}{2g} + \Delta H_e \tag{3.13}$$

where,

ΔH_e : the minor loss above the upward sill ;

$u_5 = Q_i / (B_s y_5)$.

Minor loss above an upward sill, ΔH_e , can be determined from the equation below (Yanmaz, 2001):

$$Q_i = 2.88 B_s \left(\frac{2}{3} \Delta H_e^{\ 3/2} + y_4 \sqrt{\Delta H_e}\right) \tag{3.14}$$

Equation (3.13) and Equation (3.14) are solved for y_5, and the water depth at section-5 is obtained by satisfying the limitation; $u_5 \leq 0.3$ m/s. If the limitations cannot be satisfied by the selected value of Δ_{su}, then firstly, Δ_{su} is increased up to 1.0 m. If again the requirement cannot be obtained, the width of the settling basin B_s is increased until the required condition is satisfied. In the process which B_s is incremented, all the computations are renewed from cross-section-4, since the new value of B_s must also be used in the computation step of cross-section-4. When the limitation is satisfied, the water surface elevation, K_{w5} is determined from the following equation:

$$K_{w5} + \frac{u_5^{\ 2}}{2g} = K_{w4} + \frac{u_4^{\ 2}}{2g} + \Delta H_e \qquad (3.15)$$

- Cross-section-6 : This is the section where settling basin starts. In order to find the water surface elevation at this section, the headloss through the settling basin should be determined. For this purpose, the length of the settling basin needs to be determined in order to calculate the frictional loss through the settling basin. The length of settling basin, L_s, depends on the settlement of the sediments in the settling basin which leads to the design of settling basin.

    - Design of settling basin : The most important structural part of the intake is settling basin in which sediments are settled to be flushed to the river by the flushing pipe. Therefore, a relatively steep slope is needed in order to facilitate the removal of the sediments from the bed until the end of the settling basin. A bed slope of S_{os} = 0.01 is assigned for that reason (Sungur, 1988). Another important criterion to be considered in the design of the settling basin is that although the storage section of the settling basin is filled with sediment, the basin should still capture sediment. Thus, the minimum length and depth of a settling basin should be selected to satisfy this serviceability condition. Sümer (1977) proposed the following equation for the length of a rectangular settling basin, L_s :

$$L_s = -\frac{6(\frac{u_s}{u_*})y}{K_v \lambda} \ln(1-r) \qquad (3.16)$$

where,

u_s : average flow velocity in the settling basin ;
y : depth of flow in the settling basin ;
u_* : shear velocity in the settling basin ;
K_v : Von Karman constant which can be taken as 0.42 ;

λ : a parameter as a function of dimensionless velocity, β;

r : is the sediment removal ratio.

Shear velocity can be determined from equation :

$$u_* = \sqrt{gRS_{0s}} \tag{3.17}$$

where, R is the hydraulic radius in the settling basin. Sümer (1977) proposed the relation between λ and β as :

$$\lambda = 8.87\beta^{1.17} \tag{3.18}$$

In equation (3.18), dimensionless velocity, β is expressed as:

$$\beta = \frac{W_f}{K_v u_*} \tag{3.19}$$

where, W_f is the fall velocity (see Figure 3.3).

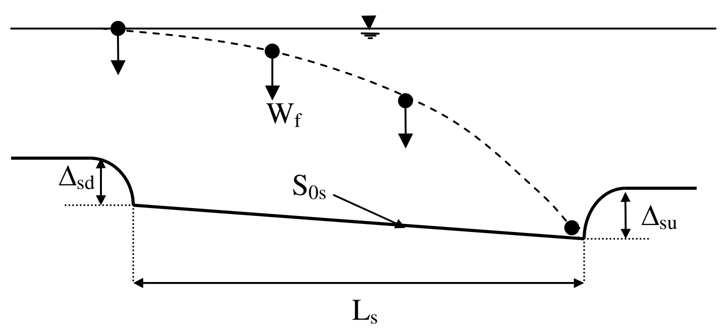


Figure 3.3. Definition sketch for settling basin design.

Fall velocity for quartz sand in water at 20^0 can be obtained from the following relations for different size of particles (Breuser and Raudkivi, 1991):

for D < 0.15 mm ; $$W_f = 663D^2 \qquad (3.20)$$

for D >1.5 mm ; $$W_f = 134.5\sqrt{D} \qquad (3.21)$$

where W_f is in mm/s and D is in mm.

Fall velocities for the particles having a diameter in the range of $0.15 \leq D \leq 1.5$ mm are given in Table 3.2.

Table 3.2. Fall velocities for quartz sand (Breusers and Raudkivi,1991).

D (mm)	W_f (mm/s)
0.15	14.8
0.2	21
0.3	36
0.4	50
0.5	64
0.6	76.4
0.7	88.6
0.8	99
0.9	110
1.0	121
1.2	137.3
1.5	166

The median size of the particle D, is the input variable such that the particles of larger sizes should be settled in the settling basin. Smaller size of particles like silt, clay and colloids are allowed to be transferred by the canal system to the fields where they have a fertilizing function. A reasonable value 0.5 mm for the input value of D can be chosen for the design of the settling basin (Yanmaz, 2001). Having calculated the fall velocity for the chosen median size, Equations (3.17), (3.18) and (3.19) are used to find necessary values u_* and λ. For the flow depth in the settling basin, y, water depth at section-5, y_5

can be used in order to have a conservative result. Average flow velocity, u_s and hydraulic radius R in the settling basin are calculated using the value of y_5. Finally, the length of the settling basin, L_s, is determined from Equation (3.16) by the substitution of the necessary variables.

The obtained value of L_s may be increased by 2.0 meters to be more conservative (Yanmaz, 2001). If the energy equation is applied between sections 5 and 6, then the water depth at the beginning of the settling basin, y_6, can be calculated:

$$y_5 + \frac{u_5^{\ 2}}{2g} + \Delta H_s = L_s S_{05} + y_6 + \frac{u_6^{\ 2}}{2g} \tag{3.22}$$

where, ΔH_s is the frictional headloss through the settling basin which is equal to:

$$\Delta H_s = \overline{S_{fs}} L_s \tag{3.23}$$

where, $\overline{S_{fs}}$ is the average of the friction slopes at sections 5 and 6:

$$\overline{S_{fs}} = \frac{\left(\dfrac{n^2 u_5^{\ 2}}{R_5^{\ 4/3}} + \dfrac{n^2 u_6^{\ 2}}{\left(\dfrac{A_6}{B_s + 2y_6}\right)^{4/3}}\right)}{2} \tag{3.24}$$

Hydraulic radius at section 5, R_5, flow area at section-6, $A_6=Q_i/u_6$ and the water depth at section-6, $y_6=Q_i/(B_s u_6)$ are inserted into Equation (3.24) and friction slopes at sections 5 and 6 are expressed by Manning's equation. Then, the only unknown u_6 is determined from Equation (3.22) and inserted into Equation (3.25) in order to find the water elevation at the beginning of the settling basin, K_{w6}:

$$K_{w5} + \frac{u_5^{\ 2}}{2g} + \Delta H_s = K_{w6} + \frac{u_6^{\ 2}}{2g} \tag{3.25}$$

- Cross-section-7 : A downward step of Δ_{sd} is placed at the entrance of the settling basin. The minor loss above this sill is recommended to be taken as ΔH_{es}=0.02 m (Sungur, 1988). Then, the flow depth of section-7 is determined from:

$$\Delta_{sd} + y_7 + \frac{u_7^2}{2g} = y_6 + \frac{u_6^2}{2g} + \Delta H_{es} \tag{3.26}$$

where $u_7 = Q_i/(B_s y_7)$ and the water elevation at section-7, K_{w7} is obtained by the following equation:

$$K_{w7} + \frac{u_7^2}{2g} = K_{w6} + \frac{u_6^2}{2g} + \Delta H_{es} \tag{3.27}$$

- Cross-section-8 : This is the section where the entrance of the intake is placed. Similar to section-3, gates are installed between the piers. The minor loss at the submerged curtain wall located at the entrance of the intake can be computed in a similar way in Equation (3.6):

$$u_8 = \frac{Q_i}{B_{sn} y_7} = K\sqrt{2g\Delta H_{ei}} \tag{3.28}$$

where, K=0.65 and B_{sn} is the net width which is equal to $B_s - n_{pi} * t_{pi}$ where, n_{pi} is the number of piers and t_{pi} is the thickness of one pier at this section. The flow depth, y_8, and the water surface elevation, K_{w8} at the upstream of the gates are calculated by the following equations:

$$y_8 + \frac{u_8^2}{2g} = y_7 + \frac{u_7^2}{2g} + \Delta H_{ei} \tag{3.29}$$

$$K_{w8} + \frac{u_8^2}{2g} = K_{w7} + \frac{u_7^2}{2g} + \Delta H_{ei} \tag{3.30}$$

- Cross-section-9 : This is the beginning of the intake which is located in front of the gates by an upward sill of height Δ_u that should be in the range of 0.5 to 1.0 meter. The purpose of the upward sill is to prevent the entrainment of the bed material into the intake. The minor loss above the upward sill, ΔH_i, is determined in the same way as Equation (3.14) except the subscripts of the variables which indicates this section:

$$Q_i = 2.88 B_s \left(\frac{2}{3}\Delta H_i^{3/2} + y_8\sqrt{\Delta H_i}\right) \tag{3.31}$$

There are also trashracks which consists of racks of bars having 6 mm thickness at the entrance of the intake to prevent the entrainment of floating objects to intake. The minor loss at the thrashracks can be determined from (Baban, 1995):

$$\Delta H_{tr} = \left(1.45 - \frac{0.45 A_n}{A_g} - \left(\frac{A_n}{A_g}\right)^2\right)\frac{u_n^2}{2g} \tag{3.32}$$

where, ΔH_{tr} : minor loss at the thrashracks ;

A_n : net area through the rack bars ;

A_g : gross area at the beginning of intake;

$u_n = Q_i / A_n$.

Finally, the water surface elevation at the entrance of the intake, K_{wi}, is determined from :

$$K_{wi} = K_{w7} + \frac{u_7^2}{2g} + \Delta H_{ei} + \Delta H_i + \Delta H_{tr} - \frac{u_8^2}{2g} \tag{3.33}$$

Once K_{wi} is obtained, the value of the upward sill, Δ_u is computed by:

$$\Delta_u = K_{wi} - K_{st} - y_8 - \Delta H_{tr} \tag{3.34}$$

where, y_8 : the water depth at section-8 ;

K_{st} : thalweg elevation at the entrance of the intake (spillway axis);

ΔH_{tr} : minor loss at the thrashracks .

If the calculated value of Δ_u is not in the range of 0.5 to 1.0 meter, then the value of the downward step at section-7, Δ_{sd} is changed and all the calculations regarding Δ_{sd} is renewed up to this point until the required condition is satisfied.

- Crest elevation of the overflow spillway : The elevation, K_{wi} obtained from Equation (3.33) is actually the crest elevation of the overflow spillway. However, in order to consider the water level fluctuations in front of the intake and further frictional losses through the intake, K_{wi} is incremented by 10 cm and the crest elevation of the spillway is obtained as:

$$K_s = K_{wi} + 0.10 \tag{3.35}$$

The height of the spillway, P is determined by subtracting the thalweg elevation, K_{st} at the spillway axis from the crest elevation of the spillway, K_s.

$$P = K_s - K_{st} \tag{3.36}$$

3.1.2.2 Determination of Spillway and Sluiceway Discharges

The river discharge is separated into two such that a large amount flows over the spillway while the rest flows through the sluiceways. Therefore, each of the discharge should be determined in order to design the energy dissipators at the toe of the spillway and sluiceways. By the continuity equation of flow, the design discharge, Q_{100}, is equal to the summation of the discharge over the spillway, Q_s and the discharge through the sluiceway, Q_{sl}:

$$Q_{100} = Q_s + Q_{sl} \tag{3.37}$$

By using Equation (3.37) as the boundary condition for the computation process, the spillway and the sluiceways discharges are found by a trial and error procedure. This procedure can be summarized with reference to Figures 3.4 and 3.5 as follows:

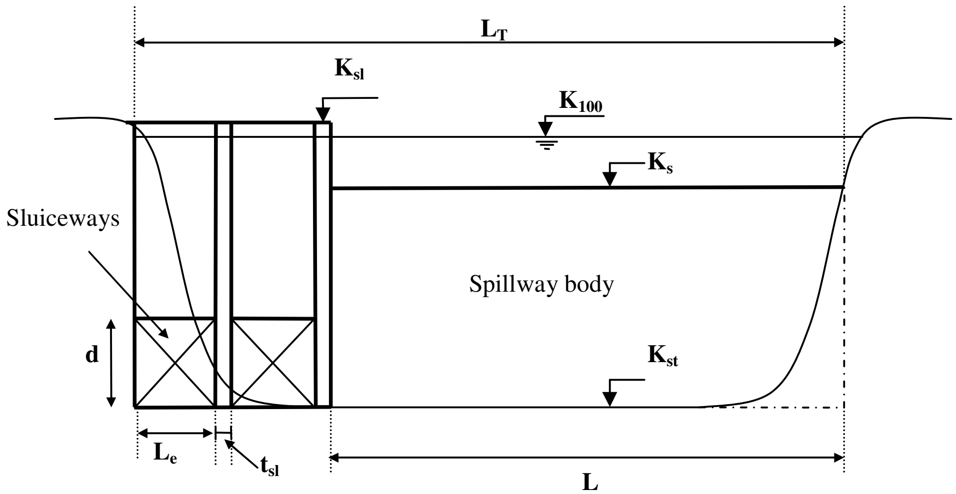


Figure 3.4. Front view of the spillway and the sluiceways.

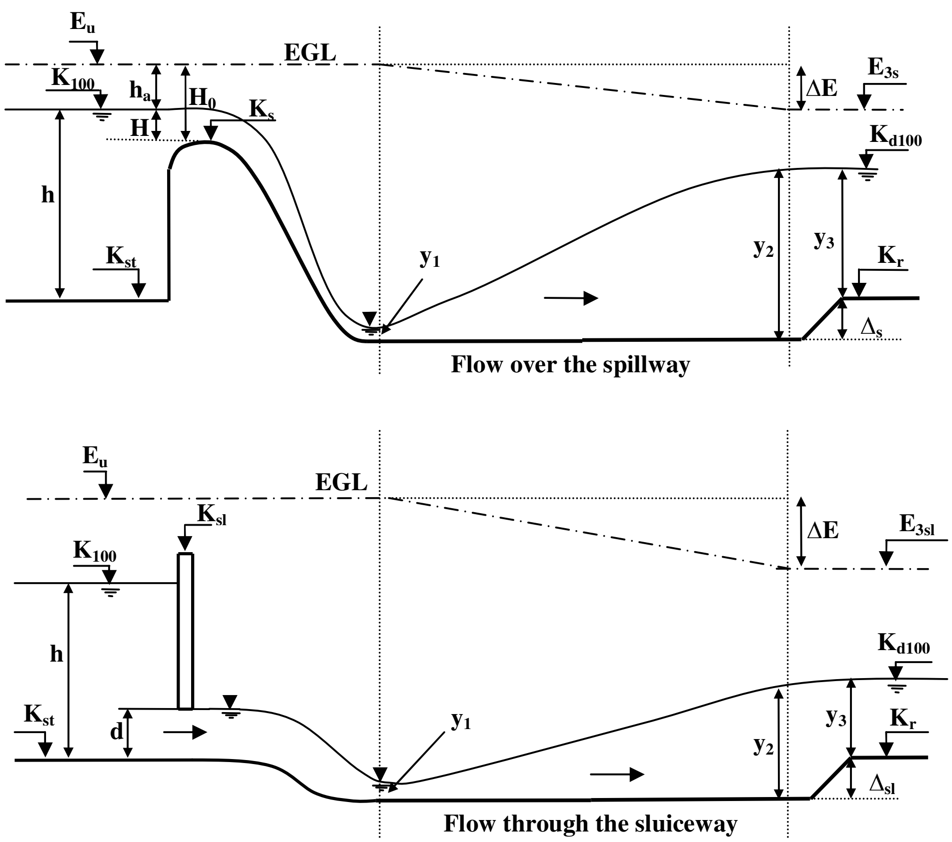


Figure 3.5. Flow over the spillway and through the sluiceway.

- The length of the valley, L_T, at the crest elevation of the spillway is measured from the cross-section at the spillway axis.

- The number of sluiceways and their corresponding dimensions are decided. This yields the crest length of the spillway, L, by subtracting the total sluiceway width from the length of the valley, L_T.

- Upstream water level, K_{100} is assumed and the corresponding water depth, h, velocity head, h_a and the total head H_0, are calculated by Equations (3.38), (3.39) and (3.40) respectively.

$$h = K_{100} - K_{st} \tag{3.38}$$

$$h_a = \frac{\left(\frac{Q_{100}}{hL_T}\right)^2}{2g} \tag{3.39}$$

$$H_0 = H + h_a \tag{3.40}$$

- Spillway discharge is computed with the data calculated above by Equation (3.41) with all necessary discharge coefficient modifications according to USBR (1987) specifications. If there are piers over the spillway, also the effective crest length should be determined. Then, the spillway discharge Q_s is obtained from:

$$Q_s = C_{om} L H_o^{3/2} \tag{3.41}$$

where, L is the crest length and C_{om} is the overall modified discharge coefficient.

- Sluiceway discharge is also calculated from Equation (3.42) with the value of the calculated water depth, h, in the following form :

$$Q_{sl} = C' n_{sl} d L_e \sqrt{2gh} \tag{3.42}$$

$$Q_{sl} = C' n_{sl} d L_e \sqrt{2gh} \tag{3.42}$$

where,

- C' : the orifice discharge coefficient that can be taken to be 0.65 as a conservative value for the sake of simplicity,
- n_{sl} : number of sluiceways,
- d : depth of sluiceways,
- L_e: width of sluiceway.

- Equation (3.37) is checked if it holds true with an allowable error. If Equation (3.37) is not satisfied, then, a new value of K_{100} is assumed and all the computations are repeated until Equation (3.37) is satisfied.

- For each flood discharge, these computations are performed and corresponding spillway and sluiceway discharges are obtained.

3.1.2.3 Design of Energy Dissipators

One of the most important part in the design of the diversion weirs is the design of energy dissipators. After the determination of the spillway and sluiceways discharges and the upstream water levels as described in the previous section, the next step is to analyze the flows at the toe of the spillway and sluiceways. Since the river flow is divided into two as over the spillway and through the sluiceways, there exist different flow conditions at these locations. Therefore, hydraulics of these locations are analyzed separately. This may result different energy dissipators at the toe of the spillway and sluiceways. The design procedure can be systemized with reference to Figures 3.4 and 3.5 as follows:

- The upstream energy elevation, E_u is computed by adding the value of h_a computed from Equation (3.39) to the upstream water level, K_{100}.

$$E_u = K_{100} + h_a \tag{3.43}$$

$$E_{3s} = y_3 + \frac{\left(\frac{Q_s}{Ly_3}\right)^2}{2g} \tag{3.44}$$

$$E_{3sl} = y_3 + \frac{\left(\frac{Q_{sl}}{(n_{sl}L_e + (n_{sl}-1)t_{sl})y_3}\right)^2}{2g} \tag{3.45}$$

where,

Q_s : Spillway discharge,

Q_{sl} : sluiceway discharge,

y_3 : the water depth at the riprap section,

L : crest length of the spillway,

n_{sl} : number of sluiceways,

L_e : width of the sluiceway,

t_{sl} : thickness of one pier.

- By ignoring the headloss at the face of the spillway and sluiceways, headloss due to the jump is obtained both for spillway and sluiceway as below:

$$\Delta E_{3s} = E_u - E_{3s} \tag{3.46}$$

$$\Delta E_{3sl} = E_u - E_{3sl} \tag{3.47}$$

- Critical water depths at the toe of the spillway, y_{cs} and the sluiceways, y_{csl} are calculated. From the ratios of $\Delta E/y_{cs}$ and $\Delta E/y_{csl}$, the conjugate depths of the jump are found.

- According to the sequent depth and the tailwater depth, the energy dissipation basin is selected (USBR, 1987). The required sill height at the downstream of the basin is also calculated.

- According to the sequent depth and the tailwater depth, the energy dissipation basin is selected (USBR, 1987). The required sill height at the downstream of the basin is also calculated.

- These calculations are performed for each flood discharge. Therefore, number of flood discharge times energy dissipation basins are designed for the toes of both spillway and sluiceways. A final single basin is selected among these alternatives by considering the worst hydraulic conditions for both spillway and sluiceway.

- If the final designed basins for the spillway and sluiceway are both of the USBR type 2,3, or 4, then the following inequality is checked to be true or not:

$$\left|\Delta_s - \Delta_{sl}\right| > 50\,\mathrm{cm} \tag{3.48}$$

  where, Δ_s is the end sill height of the spillway's stilling basin, whereas, Δ_s is of the sluiceways' stilling basin.

- If inequality (3.48) is satisfied, this means that separate stilling basins should be constructed for spillway and sluiceway divided by a wall with a common length which is determined as the maximum value among the alternatives. If inequality (3.48) is not satisfied, then a common stilling basin should be provided for both of them with the greater sill height among Δ_s and $\Delta_{sl.}$

3.1.2.4 Design of Upstream Levees

Levees are constructed in order to protect the upstream environment from flooding due to the rise of the water at the upstream of the diversion weir (see Figure 3.6). Therefore, the backwater amount should be determined. This directs to a water surface profile computation through the river at the upstream of the diversion weir. Computations are made for design discharge, Q_{100} from downstream to upstream. The downstream boundary condition is the water level over the spillway, K_{100} which is determined during the design process of the spillway and sluiceway.

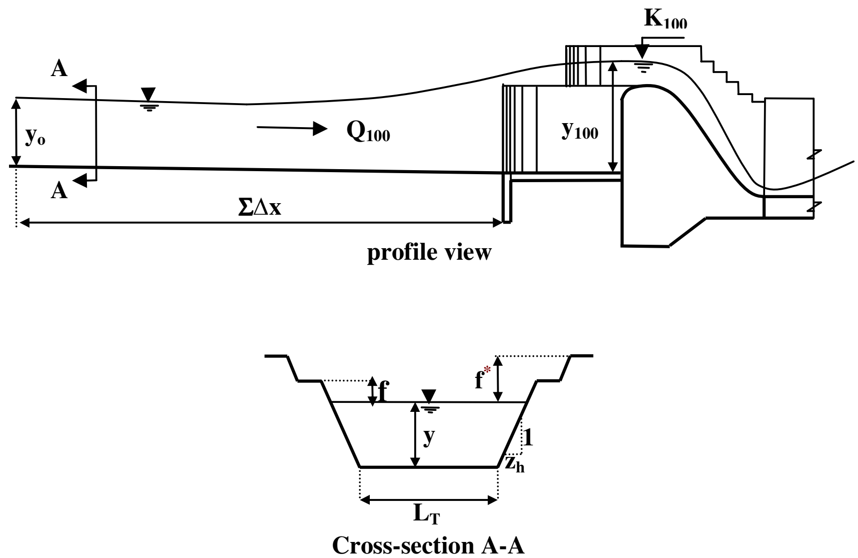


Figure 3.6. Definition sketch for upstream levees.

Water surface profile computations are carried out for a reasonable cross-section interval until the uniform flow condition at the upstream is obtained**.**

3.1.2.5 Design of Diversion Facility

Diversion facility is designed to provide a dry construction zone during the construction period of diversion weir. In order to provide a dry construction zone, cofferdams are constructed at the upstream and downstream of the diversion weir and river flow is diverted from its natural bed all the way through the construction zone by a diversion canal . Since diversion canal will serve only during the construction period of the diversion weir, it is usually designed to have a capacity of carrying flood discharges, Q_5, or Q_{10}. In Figure 3.7, a sketch demonstrating the diversion facility is presented. Diversion canal starts at a cross-section which is located approximately 100 meters upstream from the spillway axis and connects to an appropriate river cross-section at the downstream of the ripraps. The design procedure of the diversion canal is based on a cost analysis. For different values of the bottom width of the diversion canal, b, total cost of the diversion facility including the cost of the cofferdams and diversion canal is calculated and the relation between b and total cost, C_t is plotted. The value of b which gives the minimum cost is selected as the bottom width of the diversion canal, b_{op}.

In order to calculate the total cost for any value of b, first of all, a water surface profile computation through the diversion canal is performed in order to find the water depth at the beginning of the diversion canal. A downward step of height of Δ is formed at section-b as shown in Figure 3.7 in order to provide a free fall such that a boundary condition is formed to initiate water surface profile computations. The value of Δ is recommended to be about 50 ~ 60 cm which is an input variable selected by the designer provided that the condition $K_c > K_b$ is guaranteed in order to generate freefall conditions over the step where K_c is the water surface elevation over the step and K_b is the water surface elevation at section-b (see Figure 3.7). Minimum river channel elevation at section-b is known from the water surface profile computations made at the first stage of the diversion weir design.

At the free fall, the flow depth is approximately the critical water depth, y_c, which is the boundary condition. Other input needed for the water surface profile computation are Q_{10} and the average bed slope of the diversion canal which is determined from:

$$S_{odc} = \frac{K_{ta} - (K_{tb} + \Delta)}{L_{dc}} \tag{3.49}$$

where,

K_{ta} : minimum river bed elevation at section-a;

K_{tb} : minimum river bed elevation at section-b;

Δ : step height at the end of diversion canal;

L_{dc} : length of the diversion canal.

Then, with the boundary condition and the input data, water surface profile through the diversion canal is determined by starting from section-b along the length of the diversion canal, L_{dc}, whose end indicates the beginning of the diversion canal, section-a. The standard step method can be used for such a computation. As the result of the water surface profile computations, water depth, y_{max} at section-a which is the start of the diversion canal is obtained. This value also determines the height of the cofferdam, z, such that:

$$z = y_{\max} + f \tag{3.50}$$

where, f is the freeboard height which is approximately $0.2(1+y_{max})$.

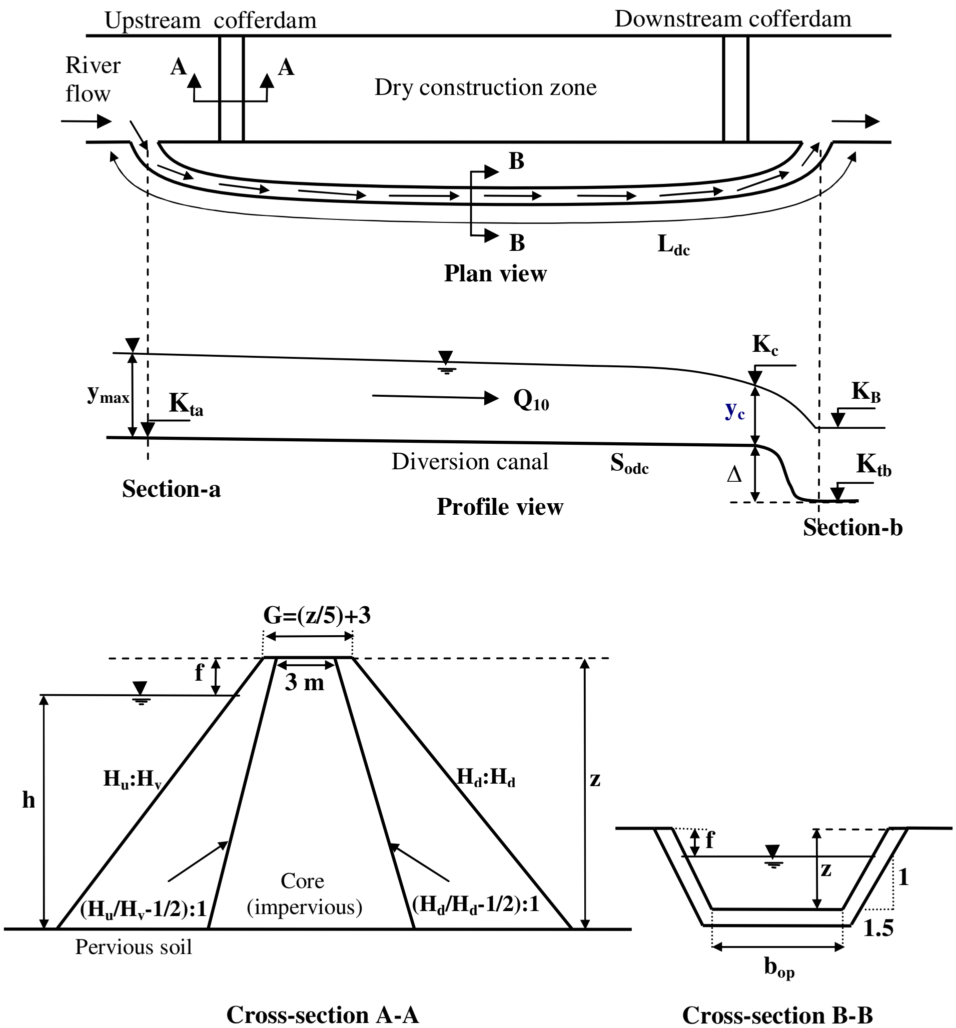


Figure 3.7. Definition sketch for diversion facility.

The next step is the determination of the cost of the diversion facility. It includes the cost of diversion canal, the upstream cofferdam and the downstream cofferdam which can be determined from the following equations (Yanmaz, 2001):

$$C_{ch} = \left[(bz + 1.5z^2)C_e + (b + 3.61z)C_l + (b + 3z + 10)C_{ex}\right]L_{dc} \tag{3.51}$$

$$C_{uc} = \left\{\left[\frac{(3+z)z}{2}\right]C_{core} + \left[\left[(\frac{H_u}{V_u} + \frac{H_d}{V_d})z + 2(\frac{z}{5} + 3)\right]\frac{z}{2} - \frac{(3+z)}{2}z\right]C_{per}\right\}L_T \tag{3.52}$$

$$C_{dc} = \left\{\left[\frac{(3+w)w}{2}\right]C_{core} + \left[\left[(\frac{H_u}{V_u} + \frac{H_d}{V_d})w + 2(\frac{w}{5} + 3)\right]\frac{w}{2} - \frac{(3+w)}{2}w\right]C_{per}\right\}L_T \tag{3.53}$$

where, C_{ch} : cost of diversion canal;

C_{uc} : cost of upstream cofferdam;

C_{dc} : cost of downstream cofferdam;

z : height of upstream cofferdam;

C_e : unit cost of excavation;

C_l :unit cost of canal lining;

C_{ex} : unit cost of expropriation;

L_{dc} : length of diversion canal;

C_{core} : unit cost of embankment core construction;

C_{per} : unit cost of embankment pervious fill construction;

L_T : width of the river at the construction site;

W : height of the downstream cofferdam which is about z-0.50;

H_u : horizontal inclination of outer layers of upstream cofferdam;

V_u : vertical inclination of outer layers of downstream cofferdam;

H_d : horizontal inclination of outer layers of downstream cofferdam;

V_d : vertical inclination of outer layers of upstream cofferdam.

Total cost of the diversion facility, C_T is calculated by adding the total costs of diversion canal, upstream cofferdam and downstream cofferdam as follows:

$$C_T = C_{ch} + C_{uc} + C_{dc} \tag{3.54}$$

As mentioned before; for different values of bottom width of the diversion canal, b, this procedure explained above is repeated until the optimum value of b is obtained. Optimum value of b is selected as the design value of the bottom width of the diversion canal.

3.1.3 Design of Some Appurtenant Facilities

In addition to the main structural elements of the diversion weir, there are some appurtenant components. The appurtenant facilities whose design procedures considered in this study are :

- Riprap design,
- Design of flushing pipe.

3.1.3.1 Riprap Design

The riprap section consists of large stones in order to protect the river bed. The size of the stones that would not subject to motion are determined by the following equation (Bayazıt, 1971):

$$D_r = 20RS_0 \tag{3.55}$$

where, D_r: diameter of the riprap;

R: hydraulic radius of the river under the design flows;

S_0: mean river bed slope.

Ripraps of diameter, D_r, are laid for the length of L_d which is determined from:

$$L_d = 3q_{100}^{\ 2/3} - 1.5y_3 \tag{3.56}$$

where, $q_{100} = Q_{100} / L_t$.

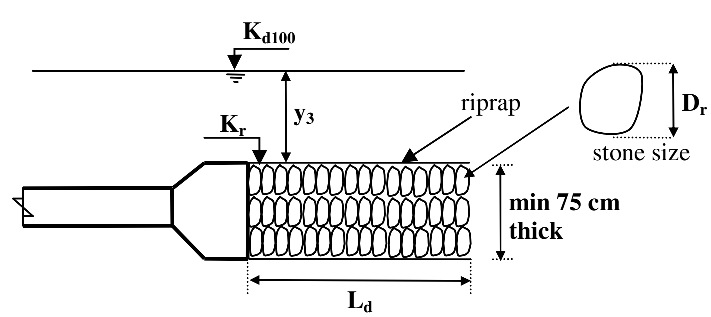


Figure 3.8. Definition sketch for riprap design.

The length of the riprap section, L_d should be at least 10 m and the thickness of the stones laid should be greater than 75 cm.

3.1.3.2 Design of Flushing Pipe

Flushing pipe is located at the end of the settling basin and connected to the river in order to discharge accumulated sediment to the river as displayed in Figure 3.9. Maximum possible size of material to be settled in the settling basin, D_m is chosen to be flushed through the flushing canal. Then, the flushing pipe diameter, D_p and the slope, S_0 of the flushing pipe is designed in order to provide discharging of the sediment of selected size D_m. The design process can be summarized as follows:

- Critical shear stress for the size of the material, D_m is determined from:

$$\tau_{oc} = \rho u_{*c}^{\;2} \tag{3.57}$$

where, u_{*c} is the critical shear velocity which initiates sediment motion and ρ is the density of water. u_{*c} is a function of material size, D_m and can be determined from the following equation for materials whose sizes are in the range of 1mm < D_m < 100 mm (Yanmaz, 2002):

$$u_{*c} = f(D_m) = 0.030\sqrt{D_m} - \frac{0.0065}{D_m} \tag{3.58}$$

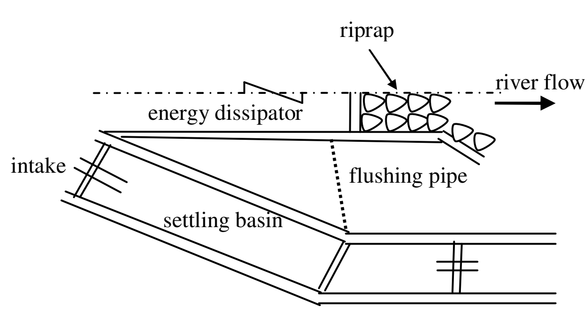


Figure 3.9. Definition sketch for the design of flushing pipe.

- A circular pipe of minimum diameter of ϕ600 mm is chosen. It is assumed that the gates of the main canal are closed during the flushing in order to guarantee pressurized flow such that the minimum bed slope corresponding to median size, D_m is selected by following trial and error procedure:

  - Shear stress in the pipe is determined from:

$$\tau_o = \frac{f_p}{8} \rho u^2 \tag{3.59}$$

    where, f_p is Darcy-Weisbach friction factor for the pipe.

  - Friction factor, f_p is obtained by rough pipe assumption such that $f_p = f(k_s/D_p)$ where k_s is the equivalent sand roughness.

  - Shear stress through the pipe, τ_o and critical shear stress τ_{oc} which is calculated from equation (3.57) is equated to calculate the pipe slope which will initiate flushing of the sediment as follows:

$$\tau_o = \frac{f_p}{8} \rho u^2 = \tau_{oc} \tag{3.60}$$

    Equation (3.60) is solved for the average velocity in the pipe that will start flushing, u.

  - By using Manning's equation, with the calculated value of u from Equation (3.60), the friction slope that will initiate the sediment motion in the pipe, S_f is determined:

$$S_f = \frac{{n_{pipe}}^2 u^2}{(\frac{D_p}{4})^{4/3}} \tag{3.61}$$

- The pipe bed slope which provide flushing is selected such that:

$$S_0 > S_f \tag{3.62}$$

so that; $\tau_0 > \tau_{oc}$.

3.1.4 Seepage Analysis

Seepage is an important concept in the design of a diversion weir, since the degree of uplift forces are highly affected by the seepage through the foundation of the spillway and energy dissipater. For that reason, an elaborate seepage analysis should be made to check if required precautions should be taken in order to overcome problems related to seepage phenomenon. In the literature, there have been many different approaches about the seepage analysis. The main methods regarding seepage analysis can be stated as:

- Finite difference techniques,
- Finite element techniques,
- Electrical analog models,
- Flow net analysis,
- Lane's creep analysis.

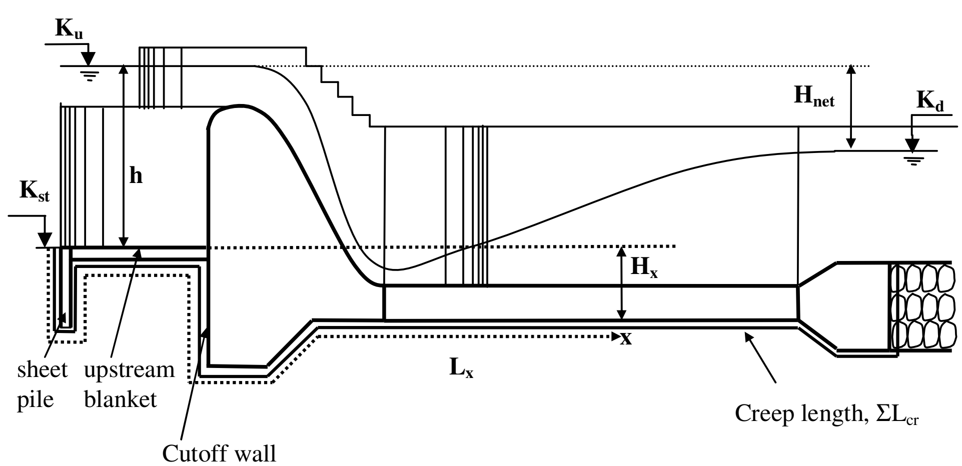


Figure 3.10. Definition sketch for Lane's creep analysis.

Finite element and finite difference techniques are sophisticated approaches in the determination of seepage through the foundation. Also, flow net analysis is quite cumbersome approach. In case of diversion weirs, a simpler method called Lane's creep analysis (USBR, 1987) is a good approach to be used for the determination of seepage. This method is based on the investigation of more than 300 diversion weirs in the U.S.A.. The minimum creep length adjacent to the structure to prevent the piping problem can be determined by this method. Piping is an important problem such that in case of high seepage, the erosion of the finer particles occur in the soil and this causes blank spaces in the soil which may accelerate the settlement of the structure. In Lane's creep analysis, the creep length is related to the effective hydraulic head, H_{net}, which is the elevation difference between the upstream and the downstream water levels, and a coefficient reflecting the relative permeability of soil, C (see Table 3.3).

Table 3.3. Values of C to be used in creep analysis (Kashef, 1987).

Foundation Material	C
Very fine sand or silt	8.5
Fine sand	7.0
Medium sand	6.0
Coarse sand	5.0
Fine gravel	4.0
Medium gravel	3.5
Coarse gravel including cobbles	3.0
Boulders with some cobbles and gravel	2.5
Soft clay	3.0
Medium clay	2.0
Hard clay	1.8
Very hard clay or hardpan	1.6

According to the field measurements of Lane, the permeability of an alluvial bed in the horizontal direction is about three times the permeability in the vertical direction. This means that the vertical seepage force is approximately three times greater than the horizontal seepage force. By considering this fact, the total creep length is determined in such a manner that the vertical lengths adjacent to structure is taken as they are, while the horizontal distances are taken as one third of their actual length. For the inclined elements: if the inclination with respect to the horizontal is greater than or equal to 45^0; that element is considered as vertical, otherwise it is taken to be a horizontal member.

The total creep length is determined by the summation of the all distances adjacent to the structure with reference to Figure 3.10:

$$\Sigma L_{cr} = \Sigma L_v + \frac{1}{3}\Sigma L_h \tag{3.63}$$

where, ΣL_{cr} : the total creep length;

ΣL_v : the total creep length in the vertical direction;

ΣL_h : the total creep length in the horizontal direction.

With the values of C and H_{net}, the required condition for the minimum creep length for no piping, L_{cr} is determined from the following condition:

$$L_{cr} \geq CH_{net} \tag{3.64}$$

Possible maximum value of the net head, H_{net}, should be considered in the inequality (3.64) in order to consider the worst condition. The cases giving different values of H_{net} are:

- Overflowing case : $H_{net} = K_u - K_d$,
- Full upstream no tailwater case : $H_{net} = K_s - K_r$.

The overflowing case is considered for each flood discharge situation. The greater value of H_{net} among all of these cases is selected for the value of H_{net} in inequality (3.64) to be on the safe side. If the condition is not satisfied, some precautions to increase the creep length should be taken, such as placing deeper sheet piles and cutoff walls or increasing the length of the upstream blanket (see Figure 3.10).

The uplift pressure at any point x of the structure needs to be determined in order to calculate the uplift force acting on the structure. After using Lane's creep analysis, if

$\Sigma L_{cr}=C^*H_{net}$ the uplift force at any point x of the structure adjacent to the foundation can be determined from:

$$u_x = h - (H_x + \frac{L_x}{C}) \tag{3.65}$$

where,

u_x : the uplift pressure head ;

h : the upstream water depth;

H_x : the elevation at point x relative to a datum which can be selected as river thalweg elevation at the spillway axis;

L_x : the creep length up to point x.

If $\Sigma L_{cr} \neq CH_{net}$, then the upstream and downstream water level difference is proportioned uniformly with respect to the total creep length where the pressure head u_x is to be determined.

3.1.5 Stability Analyses

As the last step in the design procedure of the diversion weir, the stability of the structure should be checked against various threats as follows (Yanmaz, 2001):

- Safety against sliding : The whole structure is considered.
- Safety against overturning : Only the spillway body is considered.
- Stability against uplift : The stilling basins and the settling basin are checked to be safe against uplift force causes by the seepage beneath the structures.

Usually, the governing stability problem of the diversion weirs seems to be the one against the uplift forces due to the excessive seepage beneath the structure. Therefore, some precautions which decrease the seepage forces need to be taken in order to overcome this problem. The detailed clarifications about the stability analysis is mentioned in parallel with the development algorithm of the program which is covered in Chapter 4.

3.1.6 Design of the Sidewalls

Sidewalls act like retaining walls whose crest elevations in the upstream and downstream are determined by incrementing the corresponding water levels by an appropriate freeboard value. They may be concrete gravity or reinforced concrete cantilever type depending on several conditions such as foundation material, economical concerns, stability requirements, etc. The overall dimensions of the walls are decided by according to the stability analysis such as an ordinary retaining wall design. The computational procedure regarding the design of the sidewalls is covered in Chapter 4.

CHAPTER 4

DEVELOPMENT OF THE COMPUTER PROGRAM

4.1 The scope of the Computer Program

A computer program named WINDWEIR was developed in order to carry out the optimum design of diversion weirs by considering hydraulic aspects. The program is capable of analyzing the diversion weirs with overflow spillway and sidewise (lateral) intakes. It is a user-friendly computer program that works in Microsoft Windows Operating System. Like most of the Windows programs, it has a windows based user-interface with many additional visual components. The prefix in the name of the program, WIN, emphasizes the windows based user-interface, while the name following this prefix, DWEIR, remarks the word, "diversion weir". The user-interface and algorithm of the program make it very flexible for a designer to assess various dimensions of the structure from viewpoints of safety and economy.

Diversion weirs are structures having many components. Most of the commercial hydraulic packages include more general hydraulic concepts in order to be accessed by a greater number of customers. However, this situation generates a need for hydraulic software concerning more specific type of problems. This is also true for the design of diversion weirs. The aim of this study is to satisfy these needs by combining the hydraulic computations of the components of the diversion weirs in a single computer program.

4.2 Programming Language

There are many programming languages, which are used in the development of computer programs. Each of them has some advantages and disadvantages in terms of their abilities that play important role in writing the code. In computer sciences, there exists a common idea that, a flexible programming language is usually difficult to use, and an easy language is not very flexible to develop sophisticated programs. Examples to some of the programming languages, which have strong capabilities are C, C++, etc. Contrary to these languages, Basic, Fortran 77, etc. are considered to be the kind of languages that are not flexible enough to develop complicated programs, but their usages are easy. From the programmer point of view, the criterion in selecting the programming language usually depends on the type of program to be developed. Because, there is not such a language that will always meet all the requirements of the programmer irrespective of the type of the problem which will be programmed. Therefore, a programmer should select the programming language having features which will fit his/her requirements.

Another important feature in the choice of the programming language is the support of the language for visual environment. In early days of computer sciences, most of the applications were working in a console, such as DOS environment. In parallel to the improvements in the operating systems, programming idea also changed dramatically. The most subtle change occurred is the user-interface design. With the development of the visual operating systems, such as Microsoft Windows, the visual interface concept entered to the programming languages also. One of the first programming languages, which supported visual programming, is Microsoft Visual Basic. It was easy as its predecessor, Microsoft QBasic and was giving chance to the programmer to develop visual programs that work in Microsoft Windows Operating System. Before Microsoft Visual Basic, visual programming was not very easy. Most of the time Microsoft Visual C++ was used to achieve visual interface that is a very difficult language to work with. However, since the Visual Basic was developed as a visual programming language, not only Visual Basic became popular, but also visual programming became very popular for the programmers. Nowadays, most of the programming languages have built-in supports in the language itself for visual programming, such as Borland C++, Borland Delphi, Java, Visual C++, etc.

For the final point that should be considered in selecting the programming language is its independence from the operating system to execute. In other words, in traditional programming languages like Visual C++, Visual Basic 6.0, Borland C++, etc., the program can only execute in the operating system where it was compiled. If it is ported to some other operating system, it will need to be recompiled in that operating system and a new executable file is generated for that operating system. This hampers the portability of the program. In the past years where internet was not so developed, this was not a problem, but with the wide use of internet today, this also begins to be a problem. The revolution to handle this problem was the development of the programming language, Java introduced by Sun Microsystems, Inc. Now, Microsoft also follow this vision by its programming environment, Visual Studio.NET. Microsoft Visual Basic.NET is the new version of Visual Basic that handles this portability problem. In summary, Visual Basic.NET works on a software called .NET framework which simulates the operating system. Therefore, wherever this software exists, any program that was developed by .NET programming language is able to execute irrespective of the operating system. This is an important feature, but causes a little decrease in the execution performance of the program. However, all the computer industry is in the vision of this type of programming which is seen to be the future of the programming.

In development of a program, different computer languages may be used cooperatively by some restrictions. This approach is used in some programs such that main module of the program is written in some language, and the visual interface is coded in some other language. This is especially seen in old programs which were written in DOS operating system. In order to promote them to a visual program, instead of writing all the program in a visual environment, only the interface is written with the visual language and the interface is linked with the old written program. HEC-RAS package (USACE, 1998) is an example for this approach such that the main body of the program was written in Fortran, whereas the visual interface is coded in a visual environment. However, it is better to write all the program in a visual programming language for the reason that the programmer has much more flexibility in developing the program and this yields a more flexible and user-friendly program.

At the first stage of the development of WINDWEIR, all the criteria mentioned above was evaluated and as a conclusion, Microsoft Visual Basic.NET was chosen to be the programming language of WINDWEIR. Visual Basic.NET is both a flexible and easy programming language to develop an engineering program. It has very strong capabilities that gives the programmer high flexibility in writing the program code. For the years, Visual Basic usually was not seen as a very professional language, however with Visual Basic.NET this idea changed such that most of the advanced programmers see Visual Basic.NET as a well structured, full object-oriented language. Therefore, it should not be considered as the new version of Visual Basic 6.0, it can be said as a wholly new programming language because of many number of important revisions.

Visual Basic.NET is a fully object oriented language. Classes are the main concept of object oriented programming which give more abstraction over the code modules. In Visual Basic.NET, there are many predefined classes which give the programmer to generate a very visual and complicated program. In addition to these predefined classes, the programmer can also write his/her own classes. WINDWEIR was written in a fully object oriented way such that all the code are abstracted as classes. This makes the program to be more flexible both in use and further development. In terms of civil engineering point of view, the language is highly sufficient to handle the design algorithms of diversion weirs. In terms of speed, as stated before, the program cannot be seen as fast as a program developed under C++ because of Visual Basic.NET's language characteristics. On the other hand, WINDWEIR does not need great amounts of CPU time, since it was not coded with a CPU-time consuming algorithm. Program was developed and tested on a PC with 256 MB RAM and Pentium-3, 733 MHz processor. The tests give satisfactory results in terms of program's execution efficiency. A PC having lower configuration is also sufficient to execute the program provided that a Pentium processor with 128 MB RAM is minimally recommended for an efficient use of its visual interface. The program is able to be executed on any environment providing that the .NET framework is installed on the operating system. For the time being Microsoft supports operating systems, Windows 98, Windows Me, Windows 2000 and Windows XP for the .NET framework. In future versions of Windows, Microsoft is expected to give built-in support to .NET framework . ((Davis, 2002), (Pala, 2003), (Microsoft Corporation, 2002))

4.3 Framework of the Program

As stated before, WINDWEIR is a visual program that is based on windows and many other visual components. In general, a visual program is developed by a model based on two types of programming; the main program and the visual-interface programming. WINDWEIR also follows this approach. Therefore, the framework of the program can be summarized as follows:

- Main program : As indicated in Chapter 2, a diversion weir has various structural components. Each of these components are alone different hydraulic and structural problems to be solved separately. WINDWEIR was developed for the purpose of combining the solutions of these components as a whole. Therefore, the program performs many number of computations regarding each of the components of a diversion weir having sidewise intake and an overflow spillway. In order to constitute a flexible program, it was intended to code the design of each components in different modules. Then, all of these modules which are able to work separately were combined such that the results of the modules are transferred between. As a result of this interconnection between these modules, the whole diversion weir is designed and analyzed. In other words, it may be thought that WINDWEIR consists of many small subprograms that altogether forms the main program.

- Visual-interface: This part of coding is not related to the hydraulic concepts of diversion weirs such that it consists of lines of codes related to the visual interface of the program. WINDWEIR is based on window forms as any classical program that works on Windows operating system. There are many visual components that are assembled on these windows forms which build the user-interface.

Details of the model mentioned above and corresponding solution algorithms are explained in the subsequent sections. Also, a user manual for the program is presented in Appendix A, and the source code of WINDWEIR is given in Appendix B.

4.3.1 Main Program

Main part of the program deals with the design of the structural components of the diversion weir by considering hydraulic aspects. The codes of this part form the core of the program which makes all the hydraulic computations. Each component of the diversion weir are programmed separately. Therefore, modeling of each component will be described individually by following the corresponding design procedures as explained in Chapter 3. Since comprehensive explanations about the design procedures have already been discussed in Chapter 3, this chapter cites only the explanations about the implementation of these algorithms.

4.3.1.1 Water Surface Profile Computations

As explained widely in Chapter 3, the first process in the design of the diversion weir is to perform water surface profile computations of the river in the close vicinity of the construction site. However, WINDWEIR is not capable of performing water surface profile computations. Some software packages, which are specialized for that purpose such as HEC-RAS (USACE, 1998) and BHSA (Yanmaz and Bulut, 2001) can be used in order to obtain the water surface profile. The required outputs of these computations are entered directly to the program by the user. WINDWEIR requires the following input data in order to set up further calculations:

- The minimum bed elevation of the section where the spillway is constructed, K_{st},
- The minimum bed elevation of the riprap section, K_r,
- Mean river bed slope, S_o,
- Manning's roughness coefficient of the river, n_{river},
- Water surface elevations at the riprap section (tailwater elevations) for corresponding flood discharges: K_{d100}, K_{d50}, K_{d25}, K_{d10}, K_{d5}.

4.3.1.2 Program Module for the Design of Intake

The purpose of this module is to calculate the spillway crest elevation and the overall dimensions of the intake through necessary hydraulic computations. For that purpose, calculation starts by assuming uniform flow at the beginning of the main irrigation canal. Therefore, with the input data related to the main irrigation canal, the normal depth at the beginning of the irrigation canal is calculated by Manning's equation. Starting with the total head at this section, all the headlosses through the intake are calculated from the downstream to the upstream as described in Chapter 3. The total head in front of the entrance of the intake is obtained by adding the summation of all these headlosses to the total head at the main irrigation canal according to Bernoulli's energy equation. Therefore, water surface elevation in front of the entrance of the intake is obtained and the spillway crest elevation is determined by incrementing this elevation by 10 cm.

As explained in Chapter 3, a typical intake profile is considered to be formed of nine cross-sections where headlosses occur (see Figure 3.1). Therefore, WINDWEIR makes the computations in this manner that the headlosses at each cross-section is calculated in sub-modules in the program. Throughout the computation process, there are some conditions to be satisfied, such as the flow velocity limitation at the end of the settling basin, entrance sill height limitation, etc., which are all enlightened in Chapter 3. In case the conditions are not satisfied, the necessary modifications for corresponding conditions are made and with the modifications done, the required sections are recomputed recursively until the desired conditions hold true. The flowchart illustrating the algorithm that WINDWEIR uses in the design of the intake can be seen in Figure 4.1.

The input data required for the execution of this module are listed below:

- The irrigation discharge, Q_i,
- The bottom slope of the main irrigation canal, S_0,
- The bottom elevation at the beginning of the main irrigation canal, K_1,
- The bottom width at the beginning of the main irrigation canal, B,
- Horizontal inclination of the trapezoidal main irrigation canal, z_h,
- Manning's roughness coefficient for the canal, n,
- Number of piers at the entrance of the main irrigation canal, n_p,
- Thickness of the piers at the entrance of the main irrigation canal, t_p,
- Number of piers at the entrance of the intake canal, n_{pi},
- Thickness of the piers at the entrance of the intake, t_{pi},
- Settling basin slope, S_d,
- Minimum size of sediment to be settled in the settling basin, D_m,
- Sediment removal ratio, r,
- Maximum diameter of objects entering the rackbars, D_f,
- Headloss coefficient for the transition between the main irrigation canal and intake, C_t,
- Headloss coefficient due to curvature, C_c,

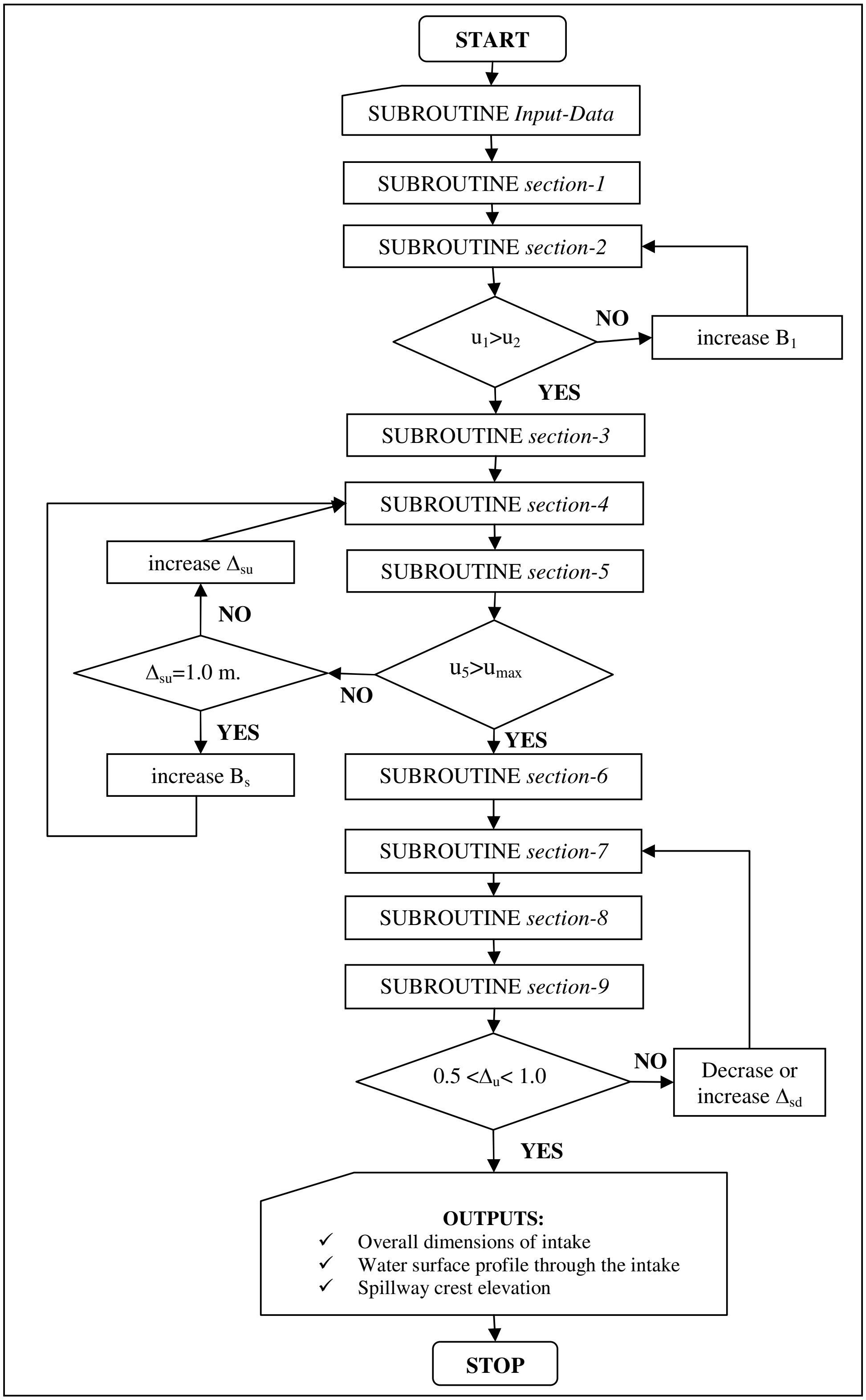


Figure 4.1. Flowchart illustrating the design of Intake.

- Maximum allowable flow velocity at the end of settling basin, u_{5max}
- Initial value for the upward sill height, Δ_{su},
- Initial value for the downward sill height, Δ_{sd},

There exists three main limitations to be satisfied throughout the execution of the module which are listed below:

- $u_1 > u_2$; flow velocity at the irrigation canal should be grater than the velocity at the end of the intake to provide inlet type of transition. The bottom width at the end of intake, B_1 is increased until this condition is satisfied.

- $u_5 < u_{5max}$; flow velocity at the end of the settling basin should be small enough to provide the settlement of the sediments. If this condition is not satisfied, firstly the value of Δ_{su} is increased up to 1 m. If still it is not satisfied, the width of the settling basin, B_s is increased until the condition is provided to be true.

- $0.5m < \Delta_u < 1.0m$; entrance sill height, Δ_u should be in the range of 0.5 m to 1.0 m. Otherwise, the value of downward sill height, Δ_{sd} is changed to provide this condition.

After the execution of the module, the following outputs are obtained which satisfy necessary limitations:

- Overall dimensions of the intake structure,
- Water surface profile through the intake,
- Crest elevation of the spillway, K_s.

Nevertheless, the main output of this module is the crest elevation of the spillway which will be used as input for the following program modules related to other structural components of the diversion weir.

4.3.1.3 Program Module for the Determination of Spillway and Sluiceway Discharges

After the execution of the module regarding to the intake design, the next process is to determine the discharges over the spillway and through the sluiceways. According to the procedure explained in Chapter 3, the upstream water elevation over the spillway and sluiceways, K, is assumed to be equal to the crest elevation of the spillway, K_s as an initial guess. The corresponding spillway discharge, Q_s and sluiceway discharge, Q_{sl} are calculated with this assumed K value and the summation of these values are checked with the total discharge. If they are equal enough with an allowable error, assumed value of K is taken as the upstream water surface elevation, otherwise the assumed value is increased until the summation of the spillway and sluiceway discharges are equal to the total discharge. The flowchart for this module is presented in Figure 4.2.

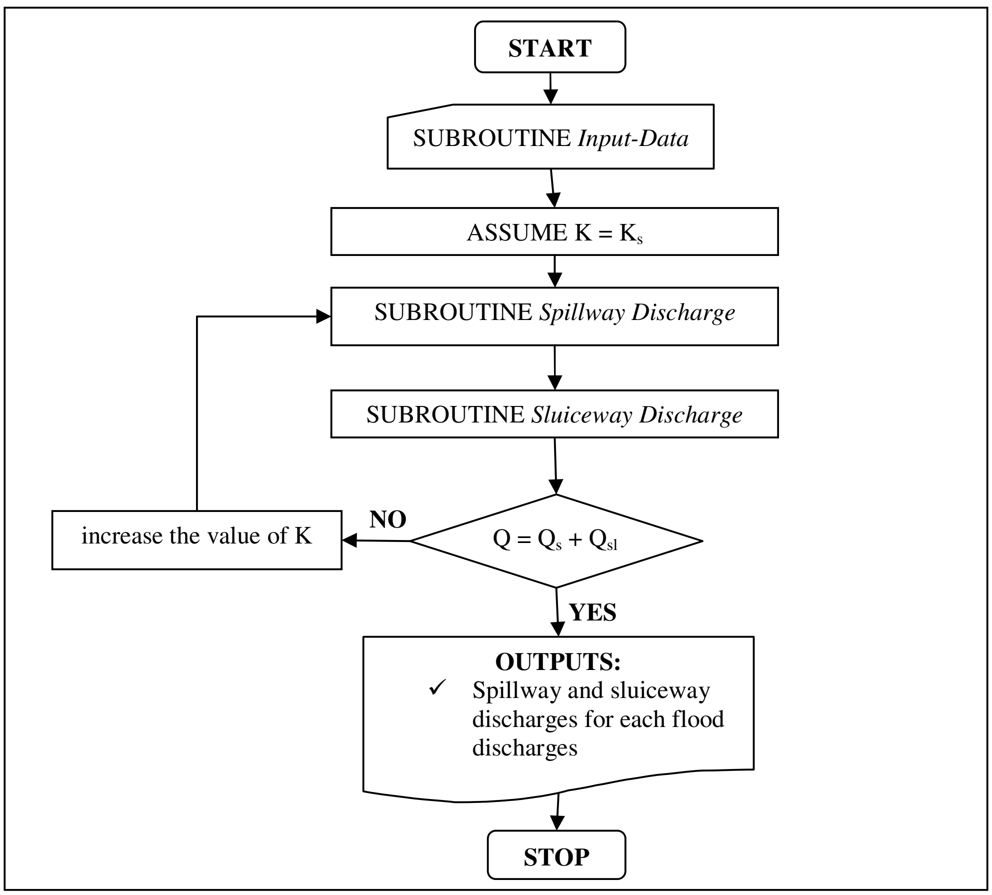


Figure 4.2. Flowchart for the determination of the spillway and sluiceway discharges.

This module of the program repeats this algorithm for each flood discharges, Q_{100}, Q_{50}, Q_{25}, Q_{10}, Q_5 and corresponding outputs for these flood discharges are obtained. The input data required for the execution of this module are as follows:

- Total valley width where spillway and sluiceways are constructed, L_T,
- Number of piers above the spillway, n_{ps} (if a bridge exists over the spillway),
- Thickness of the bridge piers, t_{ps} (if a bridge exists over the spillway),
- Contraction coefficient due to piers, K_p (if a bridge exists over the spillway),
- Contraction coefficient due to abutments, K_{ab} (if a bridge exists over the spillway),
- Width of each sluiceway, L_e,
- Number of sluiceways, n_{sl},
- Depth of the sluiceways, d,
- Thickness of walls between sluiceways, t_{sl},
- Bottom elevation at spillway section, K_{st},
- Spillway crest elevation, K_s,
- Flood discharges, Q_{100}, Q_{50}, Q_{25}, Q_{10}, Q_5,
- Water surface elevations at the riprap section for each flood discharge, K_{d100}, K_{d50}, K_{d25}, K_{d10}, , K_{d5},
- Bottom elevation at the riprap section, K_r.

The module gives the following outputs:

- Spillway crest length, L_s,
- Flow over the spillway for each flood discharge, Q_{s100}, Q_{s50}, Q_{s25}, Q_{s10}, Q_{s5},
- Flow through the sluiceways for each flood discharge, Q_{sl100}, Q_{sl50}, Q_{sl25}, Q_{sl10}, Q_{sl5},
- Upstream water surface elevations over the spillway for each flood discharge, K_{100}, K_{50}, K_{25}, K_{10}, K_5.

The outputs are used as input for the following module named; design of energy dissipators.

For the determination of spillway discharge, USBR (1987) method explained in Chapter 3 was implemented. Therefore modified spillway coefficient, C_{om} is obtained from the related graphs which are converted into following regression equations (Yanmaz, 2001):

- For the design discharge coefficient for vertical faced ogee crest, C_0:

$$C_o = -0.0201(\frac{P}{H_0})^6 + 0.2148(\frac{P}{H_0})^5 - 0.915(\frac{P}{H_0})^4 + 1.982(\frac{P}{H_0})^3 - 2.3081(\frac{P}{H_0})^2 + 1.414(\frac{P}{H_0}) + 1.7719 \tag{4.1}$$

- For the design discharge coefficient with sloping upstream face, C_{inc}:
  - For $\alpha = 18^0$;

$$\frac{C_{inc}}{C_0} = 1.04 - 0.06(\frac{P}{H_0}) + 0.04(\frac{P}{H_0})^2 - 0.01(\frac{P}{H_0})^3 \tag{4.2}$$

  - For $\alpha = 33^0$;

$$\frac{C_{inc}}{C_0} = 1.01 - 0.02(\frac{P}{H_0}) + 0.01(\frac{P}{H_0})^2 - 0.004(\frac{P}{H_0})^3 \tag{4.3}$$

- For the design discharge coefficient for varying heads, C_{me}:

$$\frac{C_{me}}{C_0} = 0.03(\frac{H_e}{H_0})^3 - 0.14(\frac{H_e}{H_0})^2 + 0.32(\frac{H_e}{H_0}) + 0.79 \tag{4.4}$$

- For the design discharge coefficient due to apron effect, C_{ma}:

$$\frac{C_{ma}}{C_0} = -30.015(\frac{h_d + d}{H_e})^6 + 246.11(\frac{h_d + d}{H_e})^5 - 836.08(\frac{h_d + d}{H_e})^4 + 1506.7(\frac{h_d + d}{H_e})^3 - 1520.1(\frac{h_d + d}{H_e})^2 + 815.14(\frac{h_d + d}{H_e}) - 180.98 \tag{4.5}$$

- For the design discharge coefficient due to submergence effect, C_{ms}:

$$\frac{C_{ms}}{C_0} = -161.95(\frac{h_d}{H_e})^6 + 416.35(\frac{h_d}{H_e})^5 - 426.22(\frac{h_d}{H_e})^4 + 224.51(\frac{h_d}{H_e})^3 - 66.258(\frac{h_d}{H_e})^2 + 11.212(\frac{h_d}{H_e}) + 0.0242 \tag{4.6}$$

where,

P :spillway height;

H_0 : total head over the spillway;

α : angle from the upstream face of the spillway to the vertical direction;

H_e: existing total head over the spillway other than the design total head;

d : water depth at the downstream (riprap section);

h_d: elevation difference between the upstream energy grade line and the downstream (riprap section) water level.

The overall discharge coefficient, C_{0m} is obtained by multiplying the effects of each aforementioned case and spillway discharge is calculated from:

$$Q_s = C_{0m} * L_s * H_0^{3/2} \tag{4.7}$$

where the definitions of the variables were already explained.

For the determination of sluiceway discharge, orifice discharge coefficient, C, is taken to be 0.65 as recommended in DSİ (1988) for simplicity. Then the sluiceway discharge is computed by the equation:

$$Q_{sl} = 0.65 n_{sl} d L_e \sqrt{2gh} \tag{4.8}$$

where h is the water depth over the sluiceway and the other variables are as explained before.

4.3.1.4 Program Module for the Design of Energy Dissipator

This module of the program is responsible for the design of the energy dissipator at the toe of the spillway. The energy dissipator design depends on the hydraulic jump phenomenon occurs at the toe of the spillway and sluiceway. Therefore, the program examines the two different hydraulic conditions at the toe of the spillway and sluiceway, respectively. Consequently, calculations are performed for both locations. According to the hydraulic jump conditions, the required energy dissipators are designed as explained in Chapter 3 (see Figure 4.3 for the flowchart of this module).

The program firstly calculates the energy levels at the upstream and downstream (riprap section) of the spillway and sluiceways for each flood discharges. By ignoring the headlosses at faces of the spillway and sluiceways, the initial water depth of the hydraulic jump is calculated from the calculated upstream energy level. WINDWEIR implements the momentum equation in order to find the conjugate of the initial water depth. Although it is not widely used, the program is also capable of solving momentum equation for stilling basins having trapezoidal cross sections. As a final process, the required sill height of the stilling basin is determined by applying the energy equation between the end of the jump and the riprap section. After obtaining the results of hydraulic jump, the required stilling basin types are selected for the hydraulic criteria given by USBR (1987). As mentioned before, for each flood discharge, the program designs two different stilling basins; one for the spillway's downstream, the other for the sluiceway's downstream. Among these designs, the program chooses the stilling basin having the maximum length for both the spillway and sluiceway toe. Similar to length of the stilling basin, the height of the end sill is chosen to be the maximum value among the sill heights. As a result, stilling basins at the toe of the spillway and sluiceway are determined. The program checks the differences between the spillway and sluiceway sill heights, Δ_s and Δ_{sl} respectively, such that:

- if $\left|\Delta_s - \Delta_{sl}\right| < 50$ cm; program chooses the greater value of the end sill and a common stilling is designed for both spillway and sluiceway provided that the longer stilling basin is selected as the common design.

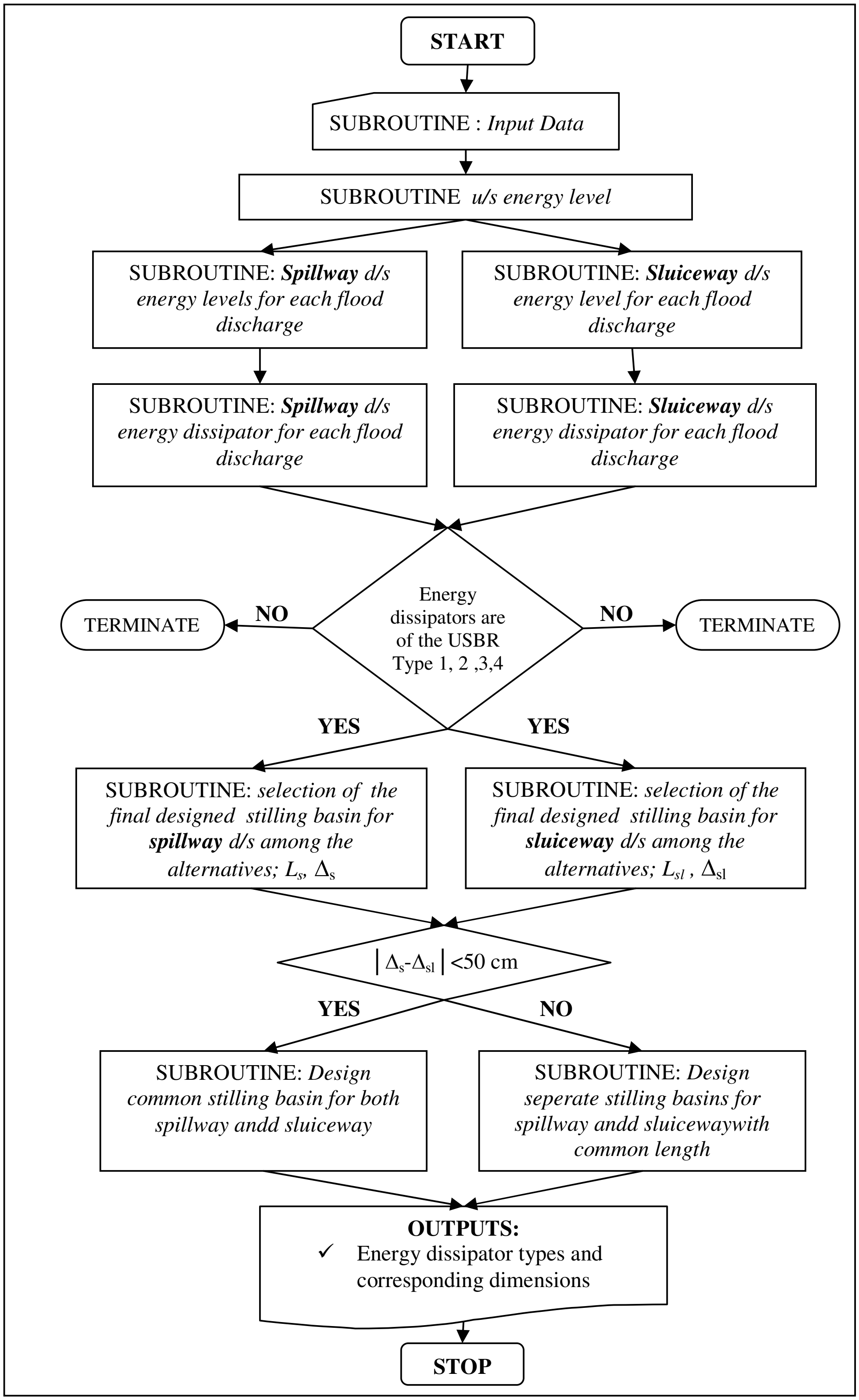


Figure 4.3. Flowchart for the design of the energy dissipators.

- if $\left|\Delta_s - \Delta_{sl}\right| \geq 50\,\text{cm}$; separate stilling basins are designed for spillway and sluiceway provided that both stilling basins have a common length but different end sills divided by a wall. The value of the common length is the greatest length among the initially calculated stilling basins.

The program is capable of designing the following types of USBR stilling basins: Type I, Type II, Type III and Type IV. Design of the energy dissipators of USBR Type V, Type VI and Type VII are not considered by the program. Whenever the program finds that these unconsidered types are needed due to hydraulic conditions, then it terminates execution by giving related error message.

The input data required for this module for execution are as follows:

- Flood discharges, Q_{100}, Q_{50}, Q_{25}, Q_{10}, Q_5,
- Flow over the spillway for each flood discharge, Q_{s100}, Q_{s50}, Q_{s25}, Q_{s10}, Q_{s5},
- Flow through the sluiceways for each flood discharge, Q_{sl100}, Q_{sl50}, Q_{sl25}, Q_{sl10}, Q_{sl5},
- Upstream water surface elevations over the spillway for each flood discharge, K_{100}, K_{50}, K_{25}, K_{10}, K_5,
- Water surface elevations at the riprap section for each flood discharge, K_{d100}, K_{d50}, K_{d25}, K_{d10}, , K_{d5},
- Bottom elevation at the riprap section, K_r,
- Bottom elevation at spillway section, K_{st},
- Number of sluiceways, n_{sl},
- Thickness of walls between sluiceways, t_{sl},
- Width of each sluiceway, L_e,
- Total valley width where spillway and sluiceways are constructed, L_T.

The outputs of this module are as follows:

- Types of the energy dissipators at the toe of spillway and sluiceway,
- Overall dimensions of both energy dissipators,
- The decision on whether a common stilling basin or separate stilling basins is to be designed.

4.3.1.5 Program Module for the Determination of Crest Elevation of Upstream Levees

In this module of the program, crest elevations of upstream levees are calculated. Water surface profile computations are carried out through the gradually varied flow which begins from the spillway axis to the upstream of the river where uniform flow starts. WINDWEIR implements the Standard Step Method for the water surface profile computations in prismatic channels (Henderson, 1966). For that reason, the portions of the river at the upstream of the spillway is modeled as a prismatic channel having a trapezoidal cross-section. The computation is performed for the design discharge, Q_{100}. Necessary amount of freeboard is added to the computed water surface profile and the crest elevations of the levees are evaluated.

Following inputs are required by the module for the determination of the water surface profile at the upstream of the spillway:

- Design discharge, Q_{100},
- Upstream water surface elevations over the spillway for design discharge, K_{100},
- Manning's roughness coefficient of the river, n_{river},
- Bottom elevation at spillway section, K_{st},
- Total valley width where spillway and sluiceways are constructed, L_T,
- Mean river bed slope, S_o,
- Cross-section interval for the water surface profile computation, Δx,
- Horizontal inclination of the trained river's side slope, z_h.

The outputs of the module are:

- Water surface profile at the upstream of the spillway until the uniform flow,
- Total length of the gradually varied flow, ΣL_x,
- Crest elevations of the levees.

4.3.1.6 Program Module for the Design of the Diversion Facility

In this module, the cofferdams and the diversion canal are designed. The program implements the cost analysis described in Chapter 3 regarding the design of diversion facility. According to that algorithm, after resolving the locations of the upstream and downstream cofferdams, the water surface profile computations between these locations are made for different bottom widths of the diversion canal. This computation repeats the cost computations for each bottom width of the canal since the cost of the cofferdams also depend on the results of the water surface profile through diversion canal.

The program starts with a bottom width of 1.0 meter and all the calculations regarding the total cost of diversion facility are made. Then, the computations are renewed by incrementing the bottom width by 10 cm. When the program finds the optimum width which gives minimum cost, it terminates execution. This optimum value yields the design of the diversion facility with corresponding dimensions (see Figure 4.4).

For the water surface profile computations, the Standard Step Method is used as in the design of the upstream levees. The required input data for this module are :

- Flood Discharge for which the diversion canal is designed, Q_{10},
- Minimum river bed elevation at the beginning of the diversion canal, K_{ta},
- Minimum river bed elevation of river cross-section to which the end of the diversion canal connects, K_{tb},
- The step height at the end of diversion canal, Δ,
- The length of the diversion canal, L_{dc},
- The width of the river at the construction site, L_T,
- Horizontal inclination of the trapezoidal diversion canal, z,
- Horizontal inclination of the upstream cofferdam's upstream slope, H_u,
- Horizontal inclination of the upstream cofferdam's downstream slope, H_d,
- Cross-section interval for the water surface profile computation, Δ_x,
- Unit cost of excavation, C_e,
- Unit cost of canal lining, C_l,
- Unit cost of expropriation, C_{ex},
- Unit cost of embankment core construction, C_{core},
- Unit cost of the embankment pervious fill construction, C_{per}.

The program module gives the following outputs:

- Optimum bottom width of the diversion canal, b_{op},

- Total cost of the upstream cofferdam of the optimum design, C_{uc},
- Total cost of the downstream cofferdam of the optimum design, C_{dc},
- Total cost of the diversion canal of the optimum design, C_{ch},
- Total cost of the diversion facility of the optimum design, C_T,
- Water surface profile through the diversion canal of the optimum design.

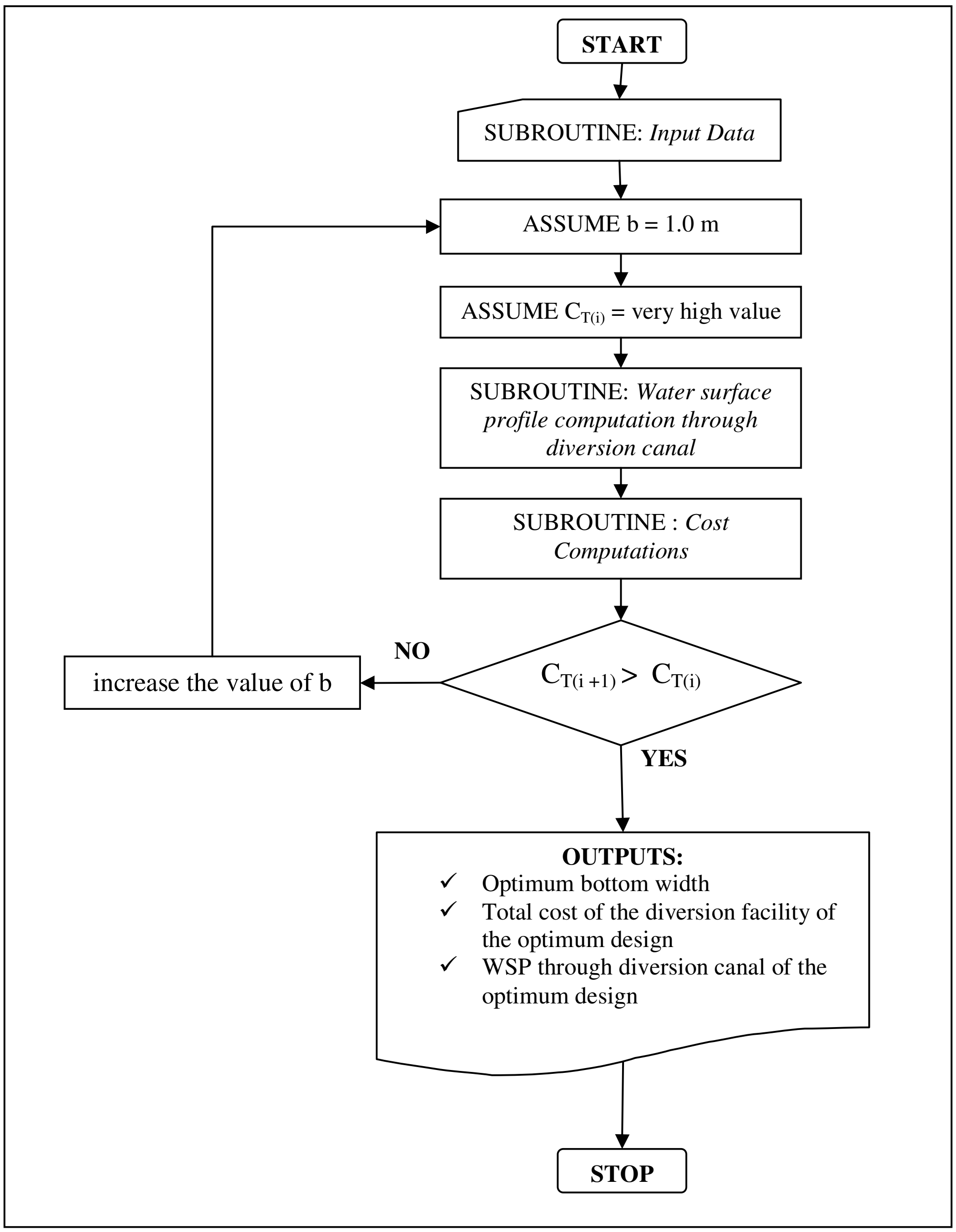


Figure 4.4. Flowchart for the optimum design of diversion facility.

4.3.1.7 Program Module for the Riprap Design

The program calculates the size of the riprap and the required riprap length in this module by applying Equations (3.55) and (3.56), respectively. If the computed length is less than the minimum required length, then the riprap length is chosen to be the. minimum required length. Also, the minimum required riprap thickness is divided into the computed riprap size in order to find the number of rows that the ripraps should be laid over. The input data of this module are as follows:

- Tailwater depth under the design flood discharge at the riprap section, y_3,
- Width of the riprap section, L_T,
- Design flood discharge, Q_{100},
- Mean river bed slope, S_0,
- Minimum riprap length, L_{d_min},
- Minimum riprap thickness to be laid, h_{r_min}.

The program gives the following outputs:

- Size of riprap, D_r,
- Length of riprap, L_d,
- Number of the rows that the stones should be laid over, n_{row}.

4.3.1.8 Program Module for the Design of Flushing Pipe

The maximum size of the material to be settled in the settling basin, D_m is taken as input to the program and the corresponding critical shear stress to facilitate sediment motion is computed by the program. For the pipe material given as input, the minimum bed slope of the pipe that will start flushing is calculated. The program selects a bed slope which is greater than this value. In order to implement this algorithm which is explained in Chapter 3, the program start by assuming a bed slope of pipe which gives the maximum possible bed slope. This assumption is reasonable, because the maximum bed slope also yields the minimum pipe length which minimizes the cost of the flushing pipe. The minimum bed slope of the pipe is obtained in a direction which is from the end of settling basin to the river cross-section where the alignment of the pipe is perpendicular with the river. By referring to Figure 4.5, the program calculates the horizontal distance of the pipe, L_p as :

$$L_p = \sqrt{L_2^{\,2} - L_1^{\,2}} \tag{4.9}$$

where; L_2 is the horizontal distance from the start of the intake to the flushing gate at the end of the settling basin, and L_1 is the horizontal projection of L_2 on the river direction which is equal to $L_2 * \cos(\alpha_i)$, and α_i is the angle between the river and the intake flow directions as seen in Figure 4.5. The pipe bed slope, S_0 is calculated from:

$$S_o = \frac{El_2 - El_1}{L_p} \tag{4.10}$$

in which, El_2 and El_1 are the elevations at the beginning and end of the pipe, respectively.

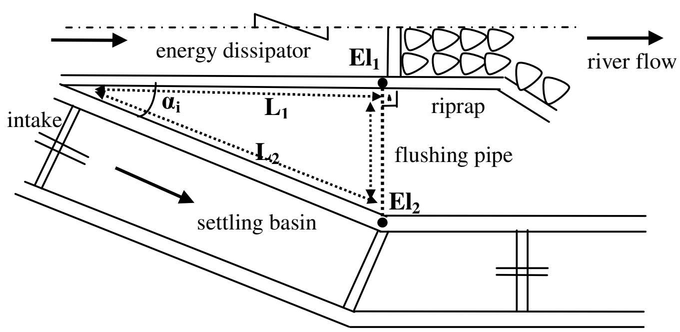


Figure 4.5. Definition sketch for the flushing pipe design algorithm.

The program assumes a pipe of minimum diameter, D_p of ϕ600 for the initial try and calculates the corresponding friction slope, S_f in the pipe that will start flushing according to the pipe material characteristics by the use of Manning's equation. A rough pipe assumption is made by the program such that Darcy-Weisbach friction factor, f_p, is calculated from the following equation:

$$\frac{1}{\sqrt{f_p}} = 2\log_{10}\frac{\frac{D_p}{2}}{k_s} + 1.75 \tag{4.11}$$

where k_s is a equivalent sand roughness and D_p is the diameter of the pipe. If the calculated friction slope smaller than the pipe bed slope, then the program stops the execution such that the flushing gate is designed with this diameter of the pipe. Otherwise, a greater pipe diameter is assumed until the friction slope in the pipe gets smaller than the pipe slope. Flowchart of this algorithm is given in Figure 4.6.

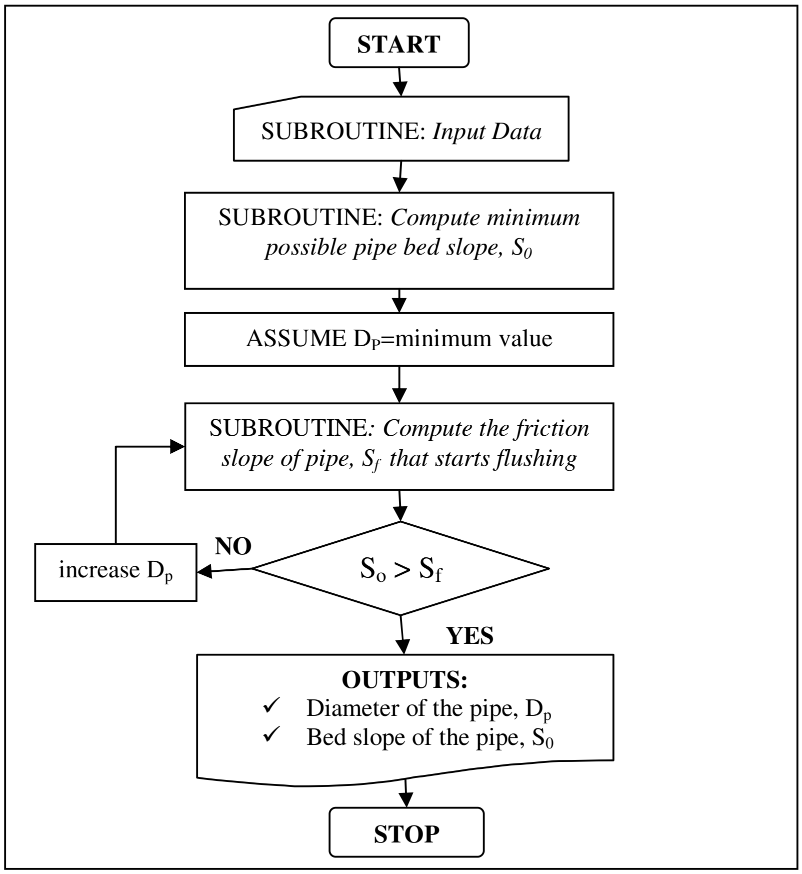


Figure 4.6. Flowchart for the design of flushing pipe.

The input data required for the execution of this module are as follows:

- Maximum possible size of the material to be flushed, D_m,
- Minimum diameter of the pipe for the initial guess, D_p,
- Manning's roughness coefficient of the pipe, n_{pipe},
- Equivalent sand roughness, k_s,
- Horizontal distance between the beginning of the intake and the end of the settling basin, L_2,

- Angle between the river and the intake flow directions, α_i,
- Bed elevation at the end of the settling basin, El_2,
- Bed elevation where the pipe connects to river, El_1.

The main outputs are:

- Diameter of the pipe, D_p,
- Bed slope of the pipe, S_0.

4.3.1.9 Program Module for the Seepage Analysis

WINDWEIR implements Lane's creep analysis for the seepage computations. Details of this method were presented in the related sections in Chapter 3. In this module, the dimensions of the foundations of the spillway are needed in order to calculate the corresponding creep length. For that reason, these dimensions are introduced as input to the module in addition to the hydraulic input data, such as the upstream and downstream water elevations for different flood discharges. Having calculated the creep length according to the foundation dimensions, it is compared with the minimum creep length which depends on the values of the relative permeability of the soil and the net head occurring between the upstream and downstream of the diversion weir.

The program does not make any modification if the minimum creep length is not satisfied. Because there are many alternatives that can be done in order to increase the seepage path, such as increasing the upstream blanket, sheet piling, cutoff walls or some other specialized precautions. It is the designer's responsibility to satisfy the seepage condition by modifying the dimensions of various structural components to increase the creep length throughout the successive executions of the program.

This module of the program performs seepage analysis by defining the foundation geometry in the following way: As it is seen in Figure 4.7, the dimensions of the foundation are described by seven number of points whose elevations and the horizontal distances between them are required input data for the program. Besides, the upstream blanket length, L_{ub}, and the height of sheet piling, H_{sp} are other necessary inputs.

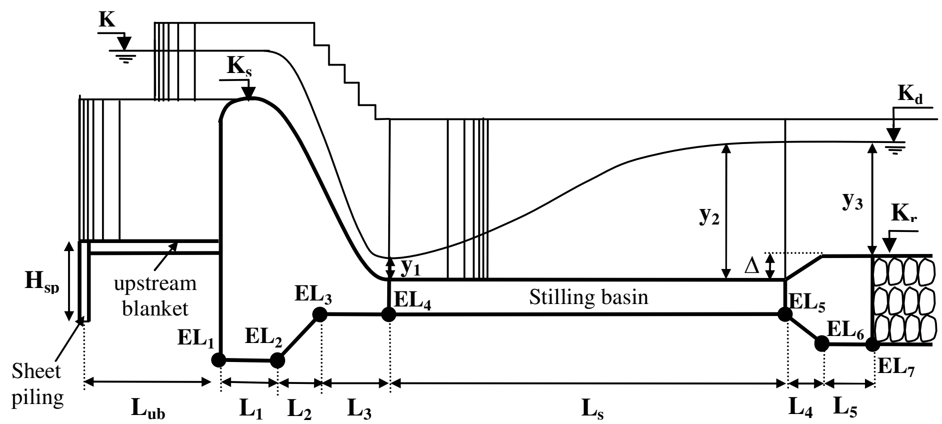


Figure 4.7. Definition sketch for the foundation dimensions of the spillway and stilling basin.

The overall input data required for the seepage analysis are listed below:

- Relative permeability of the soil, C,
- Upstream water surface elevations over the spillway for each flood discharge, K_{100}, K_{50}, K_{25}, K_{10}, K_5,
- Water surface elevations at the riprap section for each flood discharge, K_{d100}, K_{d50}, K_{d25}, K_{d10}, , K_{d5},
- Crest elevation of the spillway K_s,
- Bottom elevation at the riprap section, K_r,
- Foundation geometry as described above.

The module gives the following outcome:

- Total creep length, L_{cr},
- Minimum creep length for no piping, $C*H_{net}$,
- The end result if the structure is satisfactory or not for seepage.

4.3.1.10 Program Module for the Stability Analysis

WINDWEIR performs the stability analysis with respect to the following criteria:

- Stability against uplift,
- Stability against sliding and shear,
- Stability against overturning.

In the stability calculations, the program module follows some general policy. For each stability analysis, the forces acting on the corresponding structure are calculated and according to the need of the stability check, also the moments generated by these forces with respect to critical points of the structure are computed. Then, corresponding safety criterion is checked whether the structure is safe or not. If the structure is not satisfactory, the program does not make any alteration in the parameters, such as geometry of the structure, etc., that affect the safety in order to satisfy the criterion. This is because, there are many alternatives that can be made to provide the safety. Therefore, the necessary changes that should be done are left to the designer. The designer is responsible to satisfy the safety by changing the appropriate variables. For example, foundation elevations can be changed to increase in the weight of the corresponding structure which increases the safety. As a result, the designer should make such modifications and performs successive executions of the program until the desired criteria are satisfied.

4.3.1.10.1 Stability against Uplift

Stability analysis against uplift is carried out both for the stilling basin and settling basin. Usually a common stilling basin at the toe of the spillway and sluiceway exists as the result of the energy dissipator calculations. However, sometimes, separate stilling basins may exist at the downstreams of the spillway and sluiceway. For those cases, foundation geometries of these stilling basins become different from each other such that stability calculations against uplift should be performed separately for each part. WINDWEIR follows the same approach in stability calculations.

Throughout the stability computations against uplift, the factor that threats the safety is the uplift force produced by seepage phenomenon. Therefore whenever the uplift force needs to be computed, the corresponding creep length is also computed in order to determine the uplift force. Therefore, foundation geometry is also required for uplift calculations. Similar to spillway and its stilling basin's foundation geometry, intake foundation geometry is also composed of seven points (see Figure 4.8).

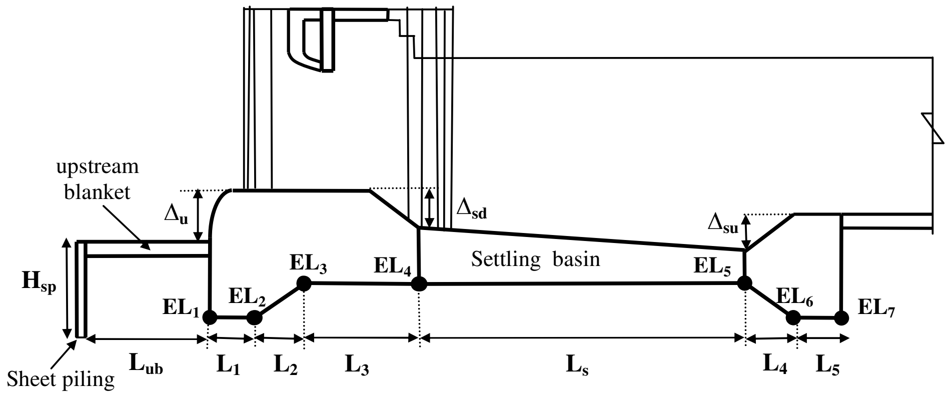


Figure 4.8. Definition sketch for the foundation dimensions of the intake and settling basin.

The program takes the required minimum factor of safety against uplift as 1.20 by default. However, the minimum factor of safety can also be input to the module to gain more flexibility. For all the uplift computations, the factor of safety against uplift is computed from:

$$FS_u = \frac{W}{F_u} \tag{4.12}$$

where, W is the weight of the basin, and F_u is the uplift force acting to the basin.

As seen in Figures 4.9, 4.10 and 4.11, stability against uplift is performed for full upstream no tailwater case which is the most risky condition in terms of safety against uplift. The weight of the stilling basin and settling basin are computed by the input data; geometry of the basins, some of which are calculated as output in the preceding modules. The seepage path is calculated from point-1 to point-2 as described in Figures 4.9, 4.10 and 4.11. For the full upstream condition, water level is taken to be the crest elevation of the spillway, K_s, by ignoring the flow over the spillway to be more conservative. However, for the settling basin, the gate is assumed to e closed with the upstream water level for design discharge, K_{100}.

If the safety against uplift is not satisfied, the program gives the message, "the filters and drains beneath the construction should be installed" and applies uplift reduction coefficient to the uplift force. Then, the program rechecks the safety criterion. If criterion is still not satisfied, then the program does not make further modification. As stated before, the designer is assumed to be responsible for further modifications to provide a safe solution.

The program module requires the following input data for processing:

- Specific weight of the water, γ_w,
- Specific weight of the concrete, γ_{conc},
- Uplift reduction coefficient, ϕ,
- Minimum allowable factor of safety against uplift, FS_u,
- Foundation dimensions of the basin,
- Height of the end sill, Δ,
- Slope of the basin, S_0 (required only for settling basin),
- Water elevation in full upstream case,
- Bed elevation at the end of the basin.

The obtained results of the module are:

- Weight of the basin, W,
- Uplift force, F_u,
- Factor of safety against uplift, FS_u,
- The end result indicating whether or not the structure is satisfactory against uplift.

4.3.1.10.2 Stability against Shear and Sliding

For the stability against shear and sliding, the overall structure (body + apron) is considered. The program makes two assumptions in the implementation of the algorithm:

1. The effects of cut off walls and passive resistance are ignored,
2. Spillway body is modeled by an equivalent trapezoidal section.

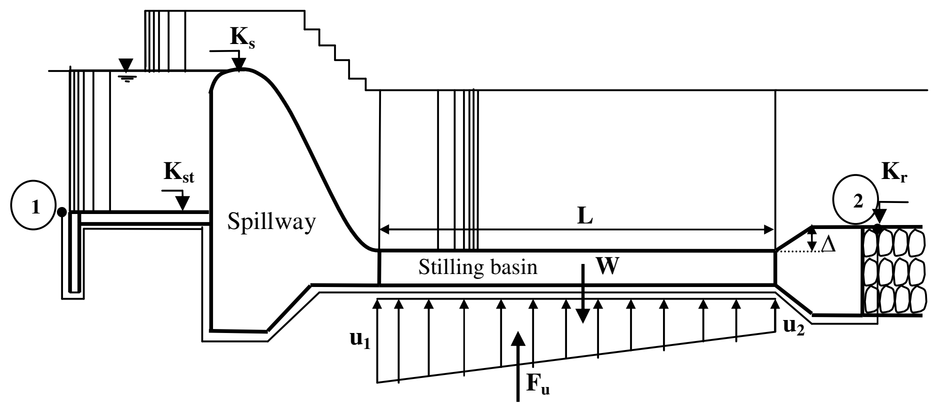


Figure 4.9. Definition sketch for the stability of spillway stilling basin against uplift.

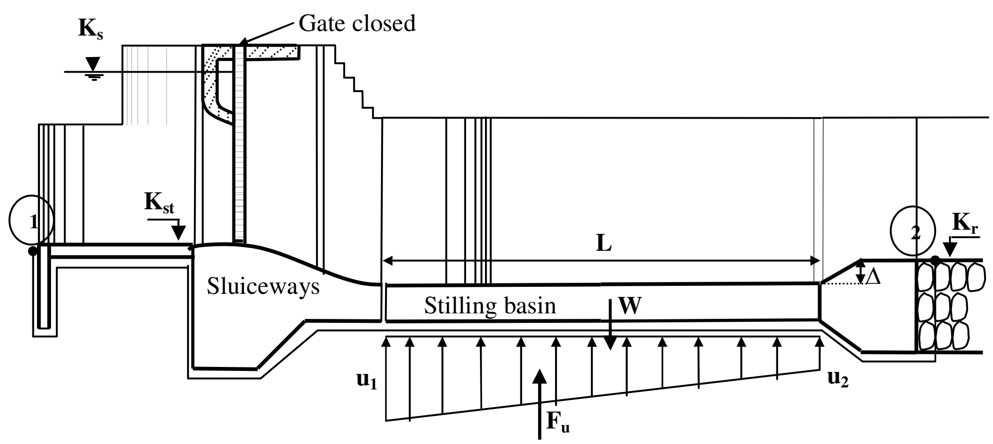


Figure 4.10. Definition sketch for the stability of sluiceway stilling basin against uplift.

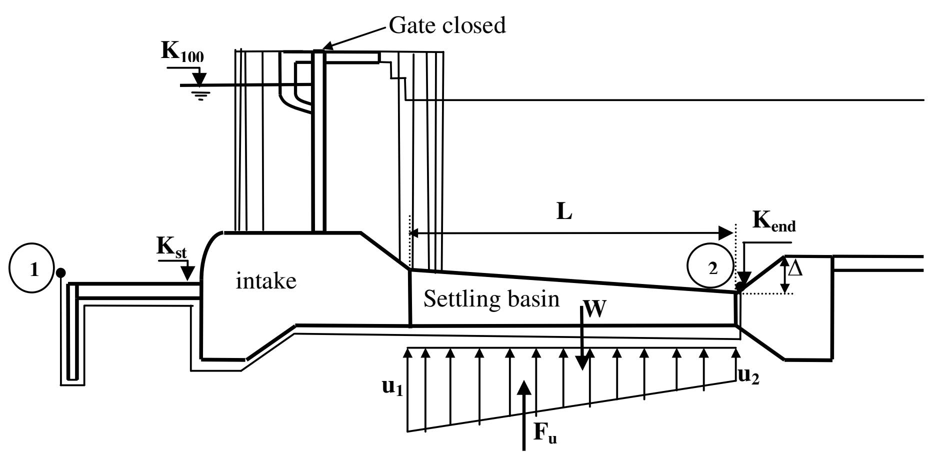


Figure 4.11. Definition sketch for the stability of settling basin against uplift.

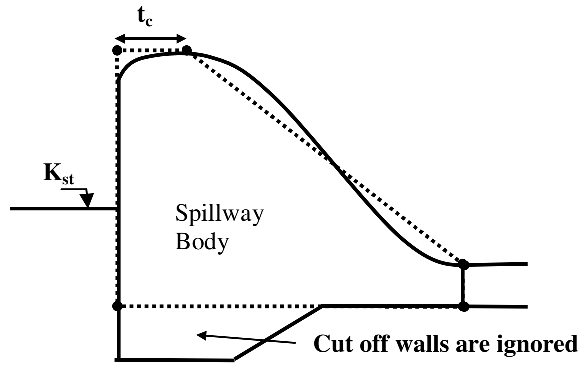


Figure 4.12. Definition sketch for the representation of spillway body with a trapezoidal section.

The equivalent trapezoidal representation of the spillway body is left to the designer. Therefore, the program requires the crest thickness of the trapezoidal section, t_c as input in order to describe the trapezoidal section (see Figure 4.12). Then, the program models the overall structure (body +apron) by ignoring the cut off walls as seen in Figure 4.13.

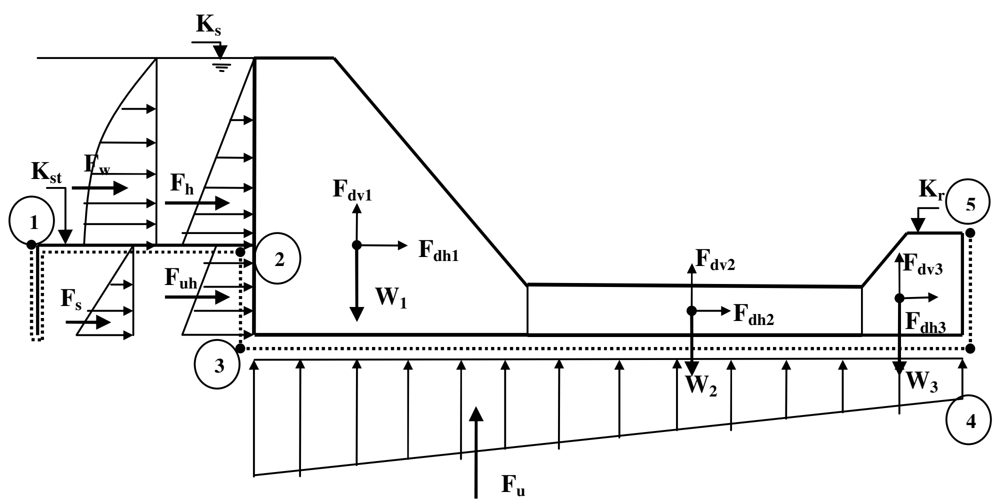


Figure 4.13. Definition sketch for stability against shear and sliding.

The definitions of the forces shown in Figure 4.13 are listed below:

- W : dead loads,
- F_u : Uplift force,
- F_d : earthquake force,
- F_h : hydrostatic force ,

- F_w : upstream dynamic force due to earthquake,
- F_s : lateral active earth pressure,
- F_{uh} : hydrostatic force acting on the subsurface portion of the spillway due to seepage.

The program does not consider the effect of ice load in the computations. The seepage path adjacent to the beneath of the modeled body and apron is computed from point-1 to point-5. According to the calculated creep length, the hydrostatic pressures at points 2, 3 and 4 are computed and the uplift force, F_u, and the subsurface hydrostatic force, F_{uh}, are determined with these uplift pressures. The computation how the seepage pressure is distributed along the seepage path was described clearly in Chapter 3. If the uplift reduction was applied in the previous module that deals with the stability against uplift, the program reduces the uplift force in this module also. The minimum factor of safety against sliding, FS_s, is computed from:

$$FS_s = \frac{f_{cf} * \Sigma V}{\Sigma H} \tag{4.13}$$

where, f_{cf} : friction coefficient between concrete and foundation,

ΣV : total net vertical force acting on the overall structure,

ΣH : total net horizontal force acting on the overall structure.

The minimum factor of safety required against shear and sliding, FS_{ss} is computed from:

$$FS_{ss} = \frac{f_{cf} * \Sigma V + 0.5 A_{sh} \tau_s}{\Sigma H} \tag{4.14}$$

where, A_{sh}: area of the shear plane,

τ_s : allowable shear stress in concrete.

The program takes the values of the minimum factor of safeties as below by default (Yanmaz, 2001):

- For sliding: 1.2,
- For shear and sliding: 3.0.

4.3.1.10.3 Stability against Overturning

In this module, only the spillway body is checked against overturning with the calculated forces in the previous module. The program performs overturning checks for the following conditions as seen in Figures 4.14, 4.15, and 4.16:

- Full upstream with no tailwater case with respect to heel of the spillway,
- Empty upstream case with respect to heel of the spillway,
- Empty upstream case with respect to toe of the spillway.

For each case mentioned above, the moments created by each force are calculated and the factor of safety against overturning, FS_0 is calculated as:

$$FS_o = \frac{\Sigma M_r}{\Sigma M_0} \tag{4.15}$$

where,

ΣM_r : total resisting moments,

ΣM_o : total overturning moments.

The program takes the minimum factor of safety to be provided against overturning as 1.5 by default. Having calculated the moments, the base pressures resulting beneath the spillway body are also checked to be in the allowable range. The base pressures, σ , are calculated by the following equation:

$$\sigma = \frac{\Sigma V}{A_{bs}} \mp \frac{M * c}{I} \tag{4.16}$$

where,

ΣV : total net vertical force acting on the base of the spillway,

M : the net moment about the centerline of the base,

c : equal to B/2, where B is the base width of the spillway body,

I : moment of inertia of the spillway base equal to ($B^3/12$),

A_{bs} : base area of the spillway.

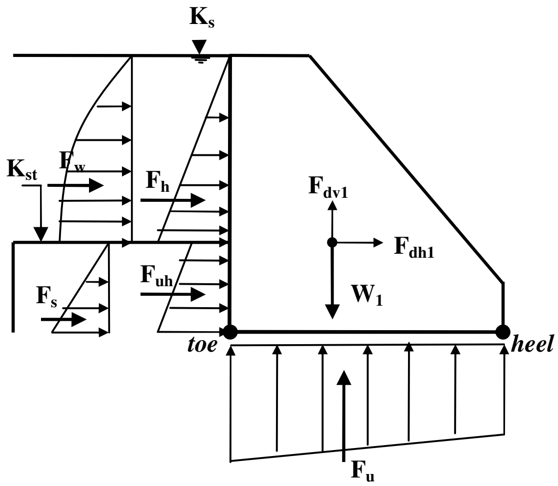


Figure 4.14. Definition sketch for stability against overturning for full upstream no tailwater case with respect to heel.

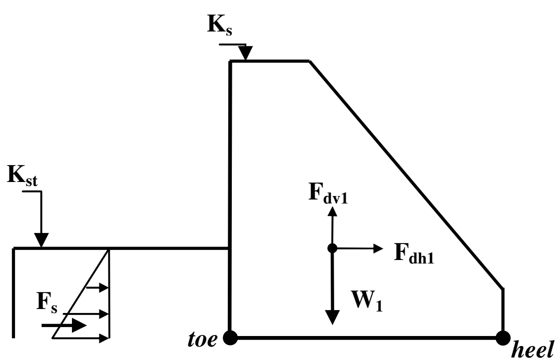


Figure 4.15. Definition sketch for stability against overturning for empty upstream case with respect to heel.

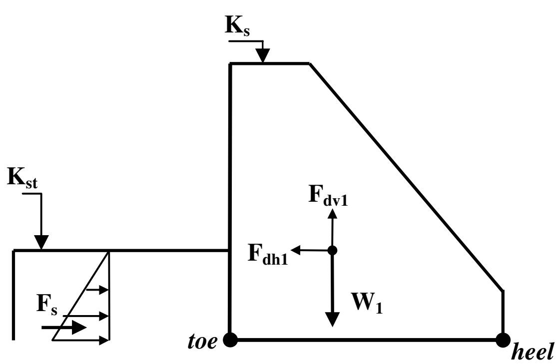


Figure 4.16. Definition sketch for stability against overturning for empty upstream case with respect to toe.

The net moment about the centerline of the base can be calculated by the relation M=ΣV*e , where e is the eccentricity which is equal to (B/2 – x). And the value of x shown in Figure 4.17 is calculated from:

$$x = \frac{\Sigma M_r - \Sigma M_o}{\Sigma V} \tag{4.17}$$

where the definitions of the variables are as explained before.

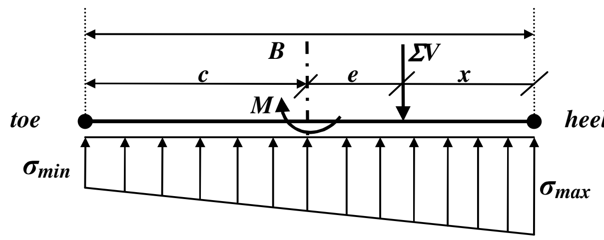


Figure 4.17. Definition sketch for calculating the base pressures.

4.3.1.10.4 Stability of the Sidewalls (Design of the Sidewalls)

The program is capable of design of cantilever type reinforced concrete retaining walls as the sidewalls. For the analysis of reinforced concrete retaining walls, Rankine's theory of earth pressure is used (Craig, 1987). Therefore, the program performs the stability analysis of the sidewalls by using Rankine's theory. The active earth pressure is calculated by the active earth pressure coefficient, K_a, as follows:

$$K_a = \frac{1 - \sin\theta}{1 + \sin\theta} \tag{4.18}$$

where, θ is the angle of repose of the soil. And the lateral active earth pressure, p_a , in a cohesionless soil is determined from:

$$p_a = K_a * \gamma * z \tag{4.19}$$

where, γ_s is the unit weight of the soil and z is the soil depth over the point considered.

The crest elevations of the sidewalls are known from the water level within the energy dissipation basin. The program determines the crest elevation from the water level at the end of the hydraulic jump, which is the sequent depth of the jump, y_2 as seen in Figure 4.7. As indicated before, energy dissipators are selected among various alternatives which each correspond to different flood discharges. Therefore, in a similar way, the maximum value of y_2 among these flow possibilities is selected and incremented by appropriate freeboard to find the crest elevation of the sidewalls, K_{sw}, as follows:

$$K_{sw} = K_{us} + y_{2,\max} + 0.2(1 + y_{2,\max}) \tag{4.20}$$

where, K_{us} is the base elevation of the stilling basin and $y_{2,max}$ is the maximum value of y_2 (see Figure 4.18).

The program requires the following dimensions of the sidewall that are illustrated in Figure 4.18 :

- Distance from the soil surface to the ground water table, d_{gwt},
- Base slab thickness of the sidewall, t_{slab},
- Thickness of the sidewall, t_{sw},
- Width of the base slab, B_{sw}.

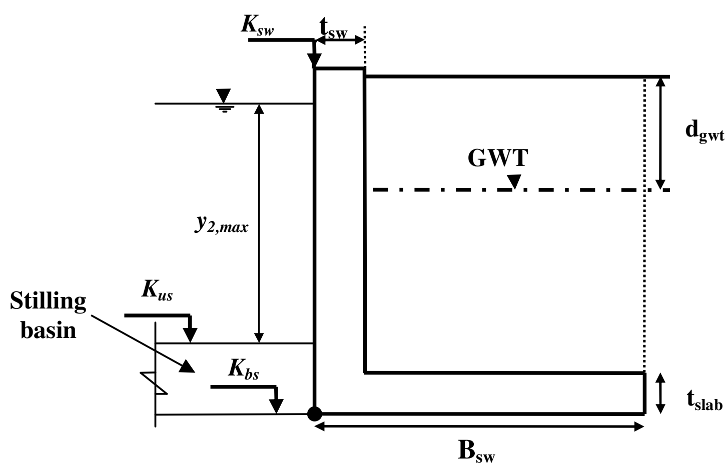


Figure 4.18. Definition sketch for the design of the sidewalls.

The program performs the stability of the sidewall against sliding with these chosen dimensions and other related data, such as the angle of repose of the soil, θ, unit weight of the soil, γ_s, etc. The program takes the minimum required factor of safety against sliding as 1.5 by default. Also, the base pressures are checked to observe if they are in the allowable limits. Therefore, all the forces acting on the sidewall are calculated and the stability checks are performed as an ordinary retaining wall. If the sidewall stability is not satisfied, then the program has an option of increasing the width of the base slab, B_{sw} until the stability is provided.

4.3.1.11 Program Module for the Computation of the Total Cost of the Diversion Weir

After the overall dimensions of the diversion weir are determined, then the total cost of the structure is evaluated from the designed dimensions of each structural component. The following components are involved in the cost computations:

- Intake,
- Spillway,
- Stilling basins,
- Gates,
- Sidewalls,
- Guiding wall,
- Riprap,
- Flushing canal,
- Diversion facility.

For the components; intake, spillway, stilling basins, sidewalls, guiding wall, the concrete volume, flushing pipe are calculated from the designed dimensions of these structures and this volume is multiplied by the unit cost of concrete which is an input value for the program. For the cost of the gates at the intake and sluiceway, the weight of the total steel used from the gate dimensions is multiplied by the unit cost of steel which is also an input value for the program. The cost of the riprap is calculated by multiplying the volume of the riprap by the corresponding unit cost. Finally, all these costs are summed up to find the total cost of the diversion weir.

The volume of the spillway body is computed from its equivalent trapezoidal representation given by the user, and the total concrete volume of USBR stilling basins are determined from the following equations (Seçkiner, 1999):

Volume of USBR type 1 stilling basin for 1 meter slab thickness, V_{sb1}:

$$V_{sb1} = Ly_1(-0.1521F_{r1}^{\ 2} + 11.487F_{r1} - 12.107) \tag{4.21}$$

Volume of USBR type 2 stilling basin for 1 meter slab thickness, V_{sb2}:

$$V_{sb2} = L(\frac{y_1^{\ 2}}{4} + 0.022y_2^{\ 2} + 4.3y_2) \tag{4.22}$$

Volume of USBR type 3 stilling basin for 1 meter slab thickness, V_{sb3}:

$$V_{sb3} = L(\frac{y_1^{\ 2}}{4} + 0.35H_3^{\ 2} + H_4^{\ 2} + 2.7y_2) \tag{4.23}$$

in which, $H_3 = \dfrac{y_1(4 + F_{r1})}{6}$ and $H_4 = \dfrac{y_1(9 + F_{r1})}{9}$

Volume of USBR type 4 stilling basin for 1 meter slab thickness, V_{sb4}:

$$V_{sb4} = L(\frac{y_1^{\ 2}}{1.75} + H_4^{\ 2} + 6.1y_2) \tag{4.24}$$

where, L is the width of the basin, y_1 and y_2 are the conjugate depths of the hydraulic jump, respectively, and F_{r1} is the Froude number at the toe of the spillway.

4.3.2 Capabilities of the Program

WINDWEIR is developed to perform the design of the diversion weirs having overflow spillway and sidewise intake. The program has built-in ability to solve two different types of problem on the subject of the diversion weirs with sidewise intake and overflow spillway:

1. The overall design of the diversion weir,
2. Optimization of the bottom width of the main irrigation canal.

The program was coded in many sub-modules, each of them was explained in the preceding sections. All these sub-modules are assembled to perform the overall design of the diversion weir. Each of these sub-modules are linked in the appropriate order as seen in the flowchart presented in Figure 4.19.

The program can also find the optimum bottom width of the main irrigation canal by an iterative cost analysis. The bottom width at the beginning of the irrigation canal, B, is initialized with 1.0 meter and the overall design of the diversion weir is done. Then, the value of B is incremented and the corresponding overall design is renewed. For each bottom width, the designed diversion weir is checked against safety for all conditions as described in preceding sections. If the diversion weir is safe under all conditions, then this is an acceptable design to be considered in the cost analysis. This computation is repeated until the bottom width that yields the minimum cost among the acceptable designs is found. The flowchart representing this procedure is presented in Figure 4.20.

4.3.3 Numerical Methods Utilized in the Program

Throughout the computation processes, many nonlinear equations are needed to be solved for the desired variables. There are many numerical techniques in the literature to find the roots of a nonlinear equation. The most common algorithms which are used in the computer programming can be listed as follows:

- Bracketing methods
    - The bisection method of Bolzano
    - Regula Falsi method
- Slope methods
    - Newton-Raphson method
    - Secant method

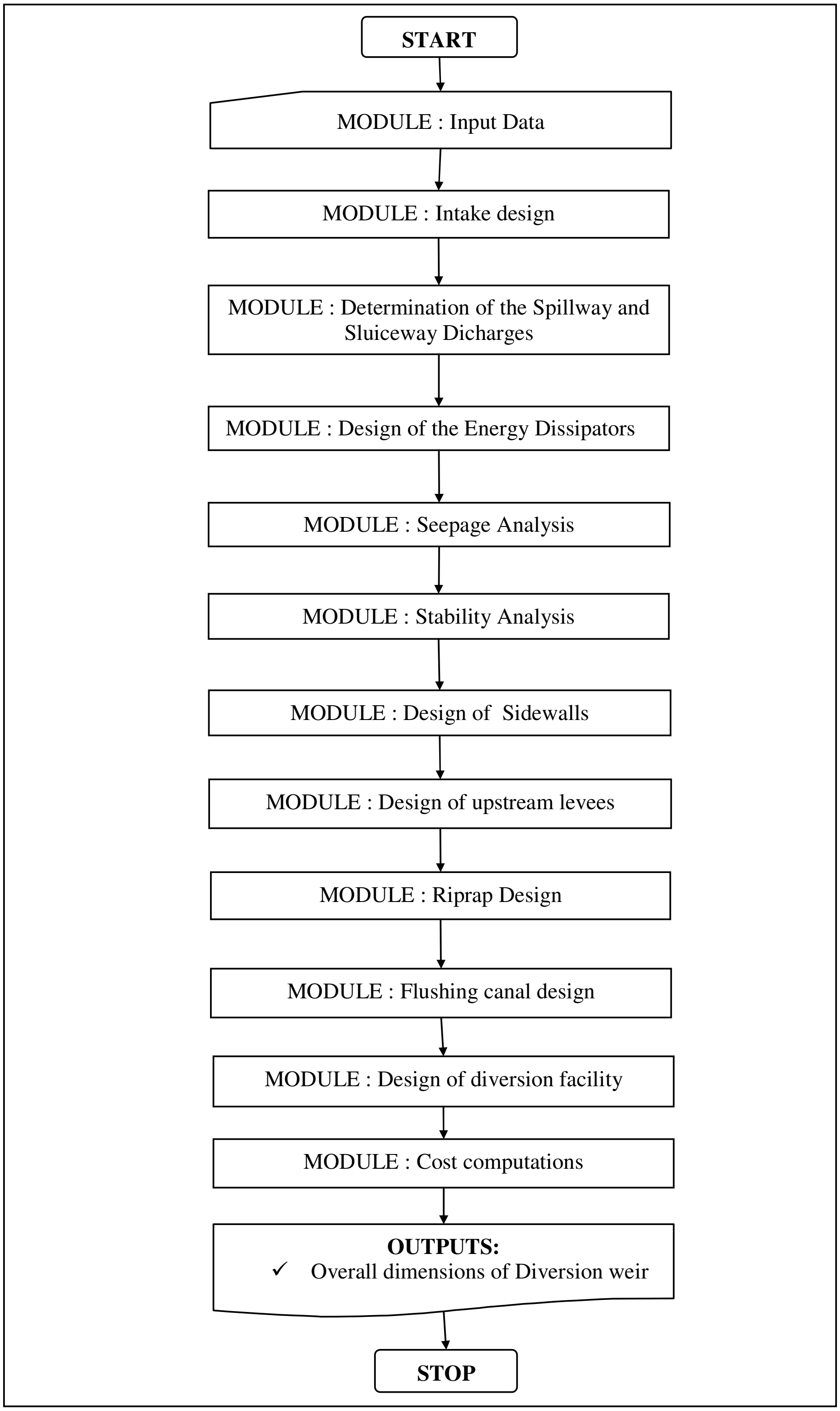


Figure 4.19. Flowchart of the overall design of the diversion weir.

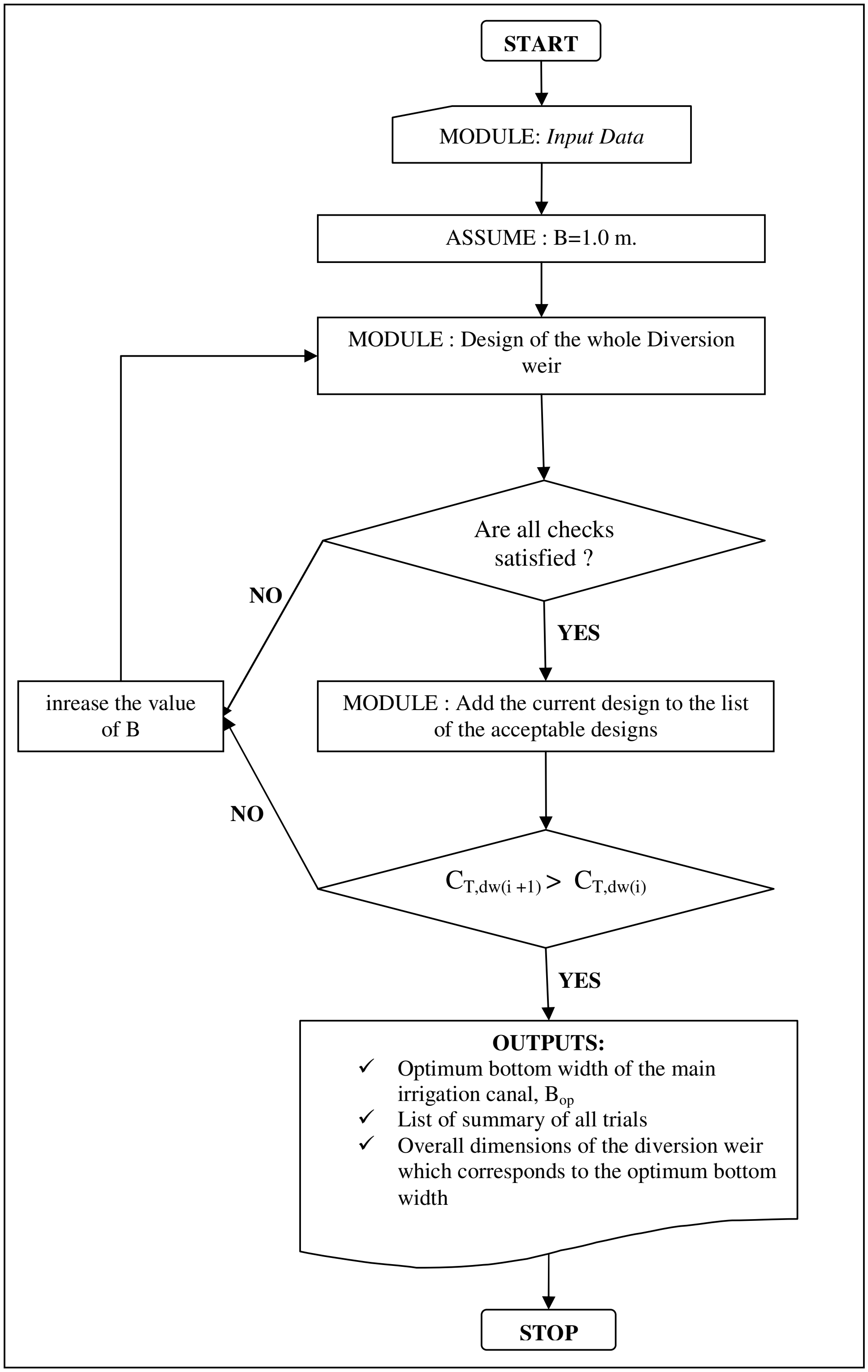


Figure 4.20. Flowchart representing the optimization of the bottom width at the beginning of main irrigation canal.

Among these methods, WINDWEIR implements Secant method to solve the nonlinear equations expressed through the design of the diversion weir. The reason behind this choice is that Secant method converges to the root faster when compared with the bracketing methods. It is also as fast as Newton-Raphson method, but it is an easier algorithm to implement.

All the nonlinear equations can be solved by using Secant method provided that the related equation itself along with its first and second derivatives are continuous functions over the range of its roots. The program calculates all the desired variables, such as critical depth, y_c, normal depth y_0, alternate depths, conjugate depths, etc by implementing the algorithm of Secant method. The details of Secant method can be found in any book related to numerical analysis.

4.3.4 Visual Interface of the Program

WINDWEIR has visual user-interface as a typical computer program that works under Microsoft Windows operating system. Overall user-interface of the program is composed of three groups:

1. User interface related to the input data,
2. User interface related to the computation process,
3. User interface related to the outputs (results).

A brief user-manual of the program in parallel with the main screenshots of the user-interfaces is presented in Appendix A.

CHAPTER 5

APPLICATION

5.1 Definition of the Problem

Hydraulic design of a diversion weir having overflow spillway and sidewise intake is to be performed by the use of WINDWEIR. The irrigation demand is diverted by the sidewise intake which is located at the right bank. The portions of the river at the upstream of the structure are assumed to be trained to have a suitable trapezoidal cross-section. Optimum bottom width of the main irrigation canal is determined by making cost analysis by WINDWEIR. In addition to these computations, the thickness of the stilling basin, length of the upstream blankets and the height of the sheet piling is varied such that the variation of the optimum bottom width of the main irrigation canal with respect to these changes are examined.

5.2 Related Information

The related input information is given as below:

- The irrigation discharge is 4.4 m^3/s,
- The bottom slope of the main irrigation canal is 0.0004,
- The bottom elevation at the beginning of the main irrigation canal is 650.10 m,
- The length of the diversion canal is 225 m,
- Relative permeability of soil , C=5,
- Friction coefficient between the structure and foundation, f=0.75,
- Manning's roughness coefficients are n_{river} =0.03 , n_{conc}=0.016,
- The specific weights are γ_{conc}=24 kN/m^3, and γ_w=10 kN/m^3,
- Allowable shear stress between the spillway and foundation =1500 kN/m^2,

- Allowable compressive strengths: Concrete: σ_{ac}=4000 kN/m^2, and Foundation: σ_{af}=3000 kN/m^2,
- The seismic earthquake coefficients: Horizontal: k_h=0.06, Vertical: k_v=0.03,
- There will be two sluiceways with suitable dimensions,
- Bed elevation at the spillway axis, K_{st} =649.20 m,
- Bed elevation at the riprap section, K_r=649.07 m.

The water surface profile computations along the river site are performed by HEC-RAS (USACE, 1998) computer package. The results of these computations which are required for WINDWEIR as input data are tabulated in Table 5.1.

Table 5.1. Input data obtained from the results of the water surface profile computations along the river site.

Flood discharge name	Discharge (m^3/s)	Water surface elevations at the riprap section (m)
Q_{100}	384	652.20
Q_{50}	324	651.98
Q_{25}	294	651.85
Q_{10}	254	651.67
Q_5	204	651.40

The unit cost values taken in the determination of the total cost of the structure are as follows:

- Unit cost of the concrete works for the spillway, stilling basin, etc., is taken as \$132.91/m^3 (Seçkiner, 1999),
- Unit cost of steel appurtenances for the steel gates is taken as 6\$ /kg,
- Unit cost of riprap is taken as 16\$/m^3.

5.3 Computations and Discussions

WINDWEIR was executed by inserting the required data presented in the previous section. Mainly, the program was executed for the following three objectives:

- To examine the effects of the thickness of the stilling basin, t_{sb},
- To examine the effects of the length of the upstream blanket, L_{ub},
- To examine the effects of the height of the sheet piling, H_{sp}.

For the first part, the cost optimization with respect to the bottom width of the main irrigation canal was made for the following values of the stilling basin slab thicknesses: t_{sb}=0.8 m, t_{sb}=0.9 m, t_{sb}=1.0 m, t_{sb}=1.1 m All the other variables are taken as constant through these alternatives in order to examine the effect of the slab thickness of the basin. For each of these values, the curves of cost versus bottom width of the irrigation canal, B, are plotted as seen Figure 5.1. The triangle symbol on the curves represents the boundary of the acceptable designs from which all of the checks including the stability analysis are satisfied. As expected, smaller bottom widths of the irrigation canal causes higher water elevations at the upstream of the diversion weir. This causes stability problems as a result of high hydrostatic and uplift forces. When the slab thickness of the stilling basin is increased, the acceptable designs start at smaller bottom widths of the main irrigation canal, because the stability of the stilling basin against uplift is satisfied by increasing the stilling basin weight. As a result, it is seen from Figure 5.1 that, the acceptable design limit shifts leftwards by the increase of the thickness of the stilling basin.

For the second part, the effect of the upstream blanket is examined. The length of the upstream blankets are increased by 4 m. Figure 5.2 shows that the acceptable design limit shifts leftward by increasing the length of the upstream blanket. As a result, if the length of the upstream blanket increases, safety of the structure increases because smaller uplift force is generated due to the increase in creep length.

For the last part of the problem, the effect of the height of the sheet piling is examined for the values of 2, 4, and 6 m by holding all the other variables as constant. As expected, deeper sheet piling reduces the uplift forces by increasing the seepage path, resulting in shifting of the acceptable design limit leftwards. This situation is clearly seen in Figure 5.3.

Among these analyses, it can be resulted that, uplift is an important problem which threatens stability by the uplift forces. Therefore, the stability against overturning or shear and sliding play secondary roles in the stability requirements. This is an expected result that the weight of the spillway body is usually enough to resist against overturning and sliding tendencies. However, the weight of the basin may not be enough to resist against the uplift forces due to seepage. As the second result from these analyses, to increase the slab thickness of the basin is a reasonable precaution to satisfy the stability against uplift.

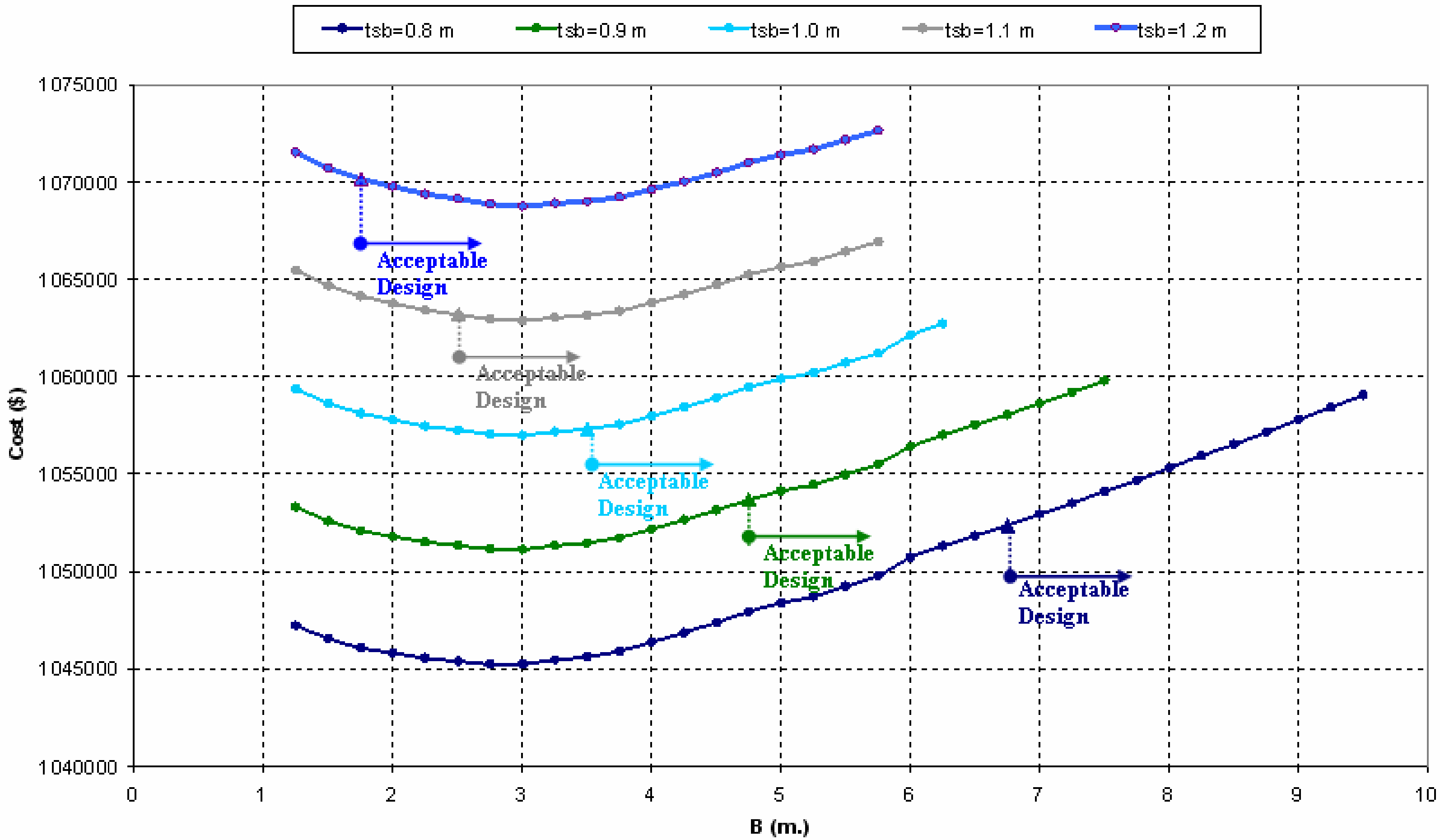


Figure 5.1. Cost versus main irrigation canal width for various thicknesses of stilling basin (L_{ub}=8.0 m, H_{sp}=2.0 m).

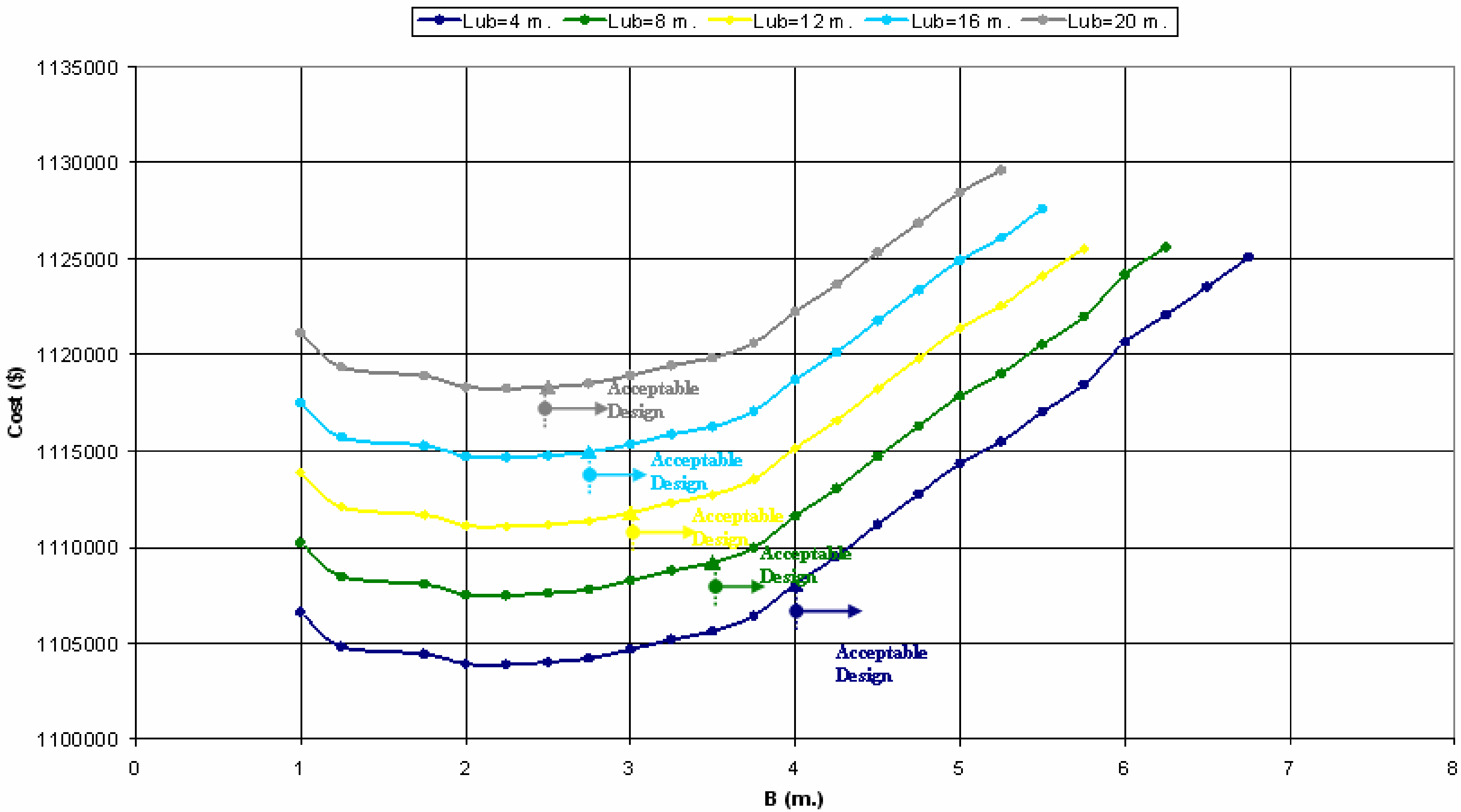


Figure 5.2. Cost versus main irrigation canal width for various lengths of upstream blanket (t_{sb}=1.0 m, H_{sp}=2.0 m).

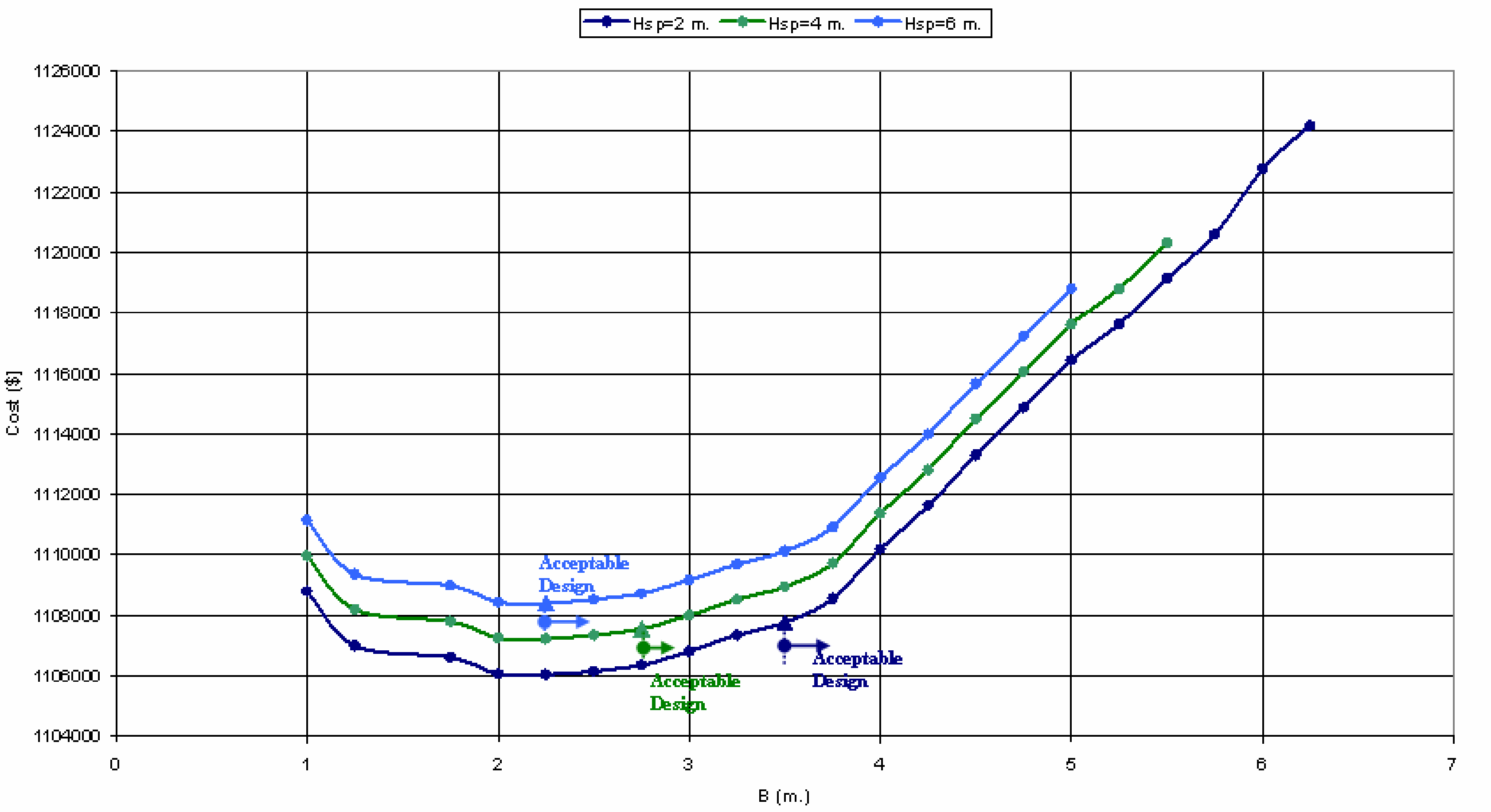


Figure 5.3. Cost versus main irrigation canal width for various heights of sheet piling (t_{sb}=1.0 m, L_{ub}=8.0 m).

An increase of 10 cm in the thickness of the slab enhance the safety against uplift in a considerable amount. Also the length of the upstream blanket can be increased to provide safety against uplift. However, the analyses show that it costs more to increase the length of the upstream blanket when compared with the increase in the slab thickness of the basin. Deeper sheet piling results lower cost with respect to upstream blanket for providing the uplift stability. This is also expected, because seepage force is smaller for the vertical direction than the horizontal direction. However, it is also not as effective as increasing of the slab thickness.

After these analyses, a designer comes to the decision stage for the assignment of appropriate values for the bottom width of the main irrigation canal, the length of the upstream blanket and the height of the sheet piling. For slab thickness of 0.8 m, the optimum bottom width of the main irrigation canal is obtained as 6.75 m whereas for the case with t_{sb}=1.1 m, the optimum bottom width corresponds to 3.0 m. Comparison of these two curves indicates that 55% reduction of the bottom width would only lead to 1% increase in the total cost, which is relatively small. Therefore, it seems that selection of 3.0 m of bottom width for the main irrigation canal is a reasonable decision considering the savings from expropriation cost due to main canal construction. Inspection of Figures 5.1, 5.2 and 5.3 indicates that smallest costs are obtained for fixed values of L_{ub}=8.0 m and H_{sp}=2.0 m under various possibilities of slab thicknesses. Therefore, it is advisable to choose B=3.0 m, L_{ub}=8.0 m, and H_{sp}=2.0 m.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

A user friendly computer program which has a visual user-interface is developed for the optimum design of diversion weirs with reference to all corresponding hydraulic computations in an integrated manner. It enables the designer to assess various dimensions of the structure from viewpoints of safety and economy. The program covers the type of diversion weirs having overflow spillway and sidewise intake.

The program should be executed on the assumption that the site is ready for construction with excavation, filling and foundation treatments were completed. Also, the soil beneath the structure is assumed to be homogenous in the design algorithms of WINDWEIR.

Almost all of the structural components of a diversion weir with sidewise intake are considered by the program. Each component is analyzed for a particular hydraulic condition with desired conformity and the overall dimensions of this component are determined by satisfying the necessary stability criteria. Optimum design can be selected among several alternatives by executing the program in an iterative manner.

The program is also able to perform cost analysis in order to determine the optimum design with respect to the bottom width at the beginning of the main irrigation canal. The capabilities of the program enables a designer to solve different types of problems related to diversion weirs, such as planning and design of irrigation systems. In this manner, optimum irrigation discharge which corresponds to maximum crop yield of an irrigation system can be obtained by performing cost analysis including the total costs of both diversion weir and the irrigation system by successive execution of the program.

The program is specifically developed for diversion weirs having an overflow spillway. As a suggested further study, the scope of the program can be extended to consider other types of diversion weirs, such as gated diversion weir and the diversion weirs with drop and frontal intakes. Also the optimization algorithms can be sophisticated in a manner that the design of the irrigation system can also be added to the program.

It is believed that a design engineer can evaluate various alternatives for the dimensions of a diversion weir by successive executions of the program and select the feasible design by considering the safety and economy. The designer may then achieve the final design among these alternatives by examining the corresponding outputs of the program by considering also the local site conditions and the purpose of the project.

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APPENDIX A

USER-MANUAL FOR WINDWEIR

A.1 Main Window of WINDWEIR

After an introductory screen appears, the main window of the program comes to the screen as seen in Figure A.1. This window is the major user-interface through which all the desired manipulations are performed. It appears during the running of the program in the computer memory such that when it is closed, then the program ends. There are five main menu items on this window. Each menu item includes some sub-menu items, which are related to the different modules of the program. These major menu items are named as follows in order of their appearances from the left to the right on the window:

- File,
- Input Data,
- Run,
- Outputs,
- Help.

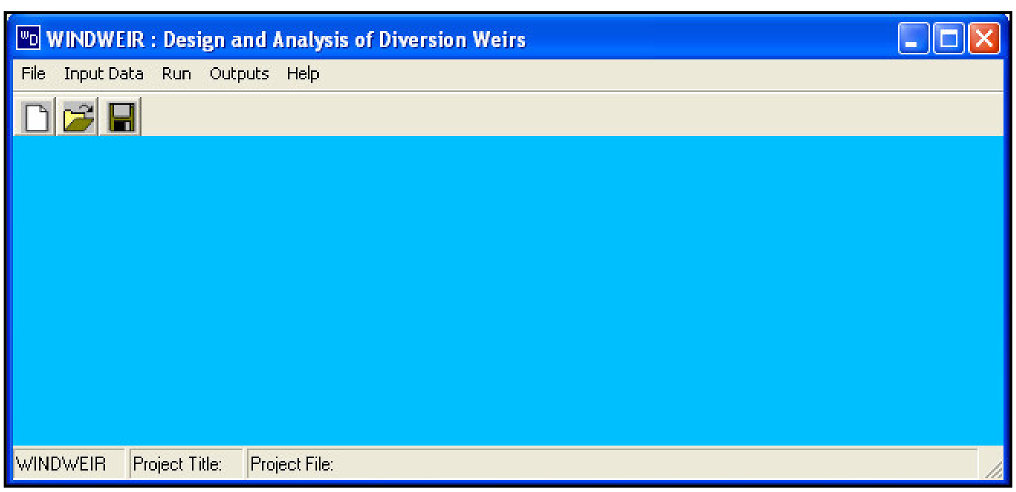


Figure A.1. Main window of WINDWEIR.

Just at the bottom of the main menu items, there exists a toolbar with some buttons which are shortcuts for mostly used sub-menu items. At the bottom of the window, there is a status bar which includes some information about the working program, such as the project title and the location of the project file on disk.

A.2 Menu Items in WINDWEIR

Since there are many actions that can be performed in the program, the user-interface contains many menu items. Therefore, all of these menu items are grouped according to their relation to the sub-modules of the program. Each menu item, which forms the main user-interface is explained in the following subsections.

A.2.1 Menu Items Related to the File Management

Under the menu item, named "File", there exists seven sub menu-items (see Figure A.2), which are all explained as follows:

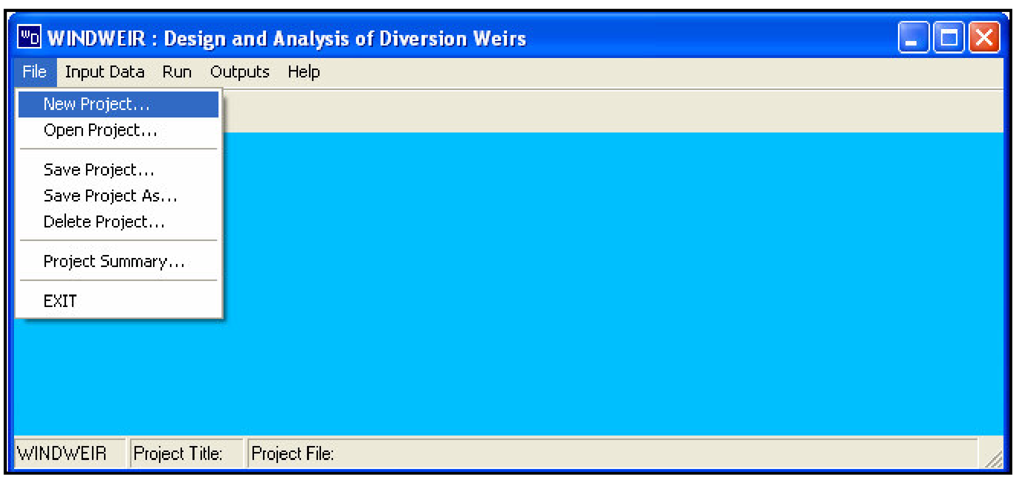


Figure A.2. Menu items related to the file management.

- New Project : By clicking this menu item, a small window appears in order to initiate a new project (see Figure A.3). There are two options that can be selected. The first one is to start a project for the design of the whole diversion weir and the second one is to start a project for the design of the selected component of the diversion weir.

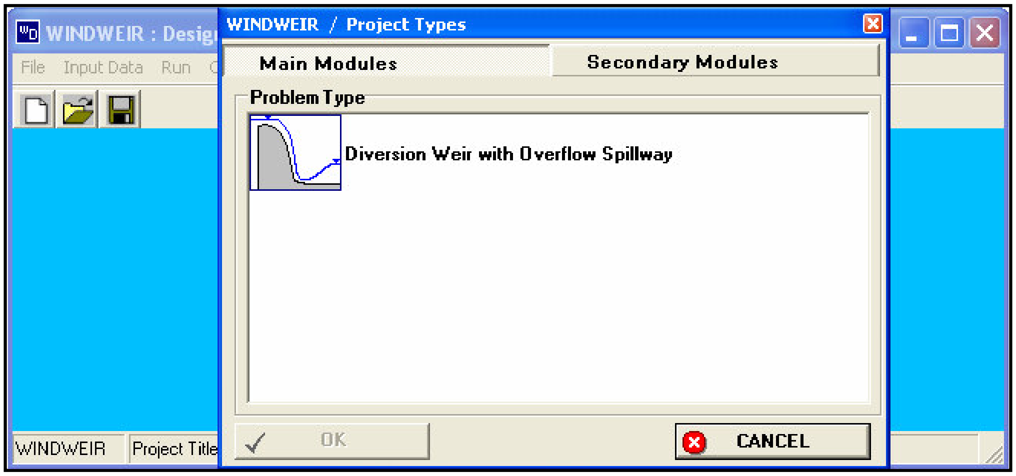


Figure A.3. Window for selecting the project type.

After the desired option is selected, the program starts such that all the variables in the program are assigned to their default values. The following part of the manual includes the explanations related to the design of whole diversion weir case. For the other options, the user-manual included in the program should be followed.

- Open Project : By clicking this menu item, a window for the selection of the project files appears and the project file to be opened is chosen by the user. The project file extension of WINDWEIR is ".dwr".

- Save Project : This menu item saves the working project on the program. If this is the first time to save the project, a new window appears such that the location and the name of the project file to be saved are required. Otherwise, the project is saved over the existing project file.

- Save Project As : If the project is desired to be saved on another location than the existing location, this menu item is used.

- Delete Project : This menu item deletes the selected project from the disk.

- Project Summary : By this window, some information about the project can be entered, such as the name of the project engineer, title of the project or some comments about the project.

- EXIT : This menu item ends the program by removing the executing file from the computer memory.

A.2.2 Menu Items Related to the Input Data

There are many input data required for the design of a diversion weir. Therefore, all of these are grouped for the sake of simplicity (see Figure A.4). These input data are grouped under following sub-menu items:

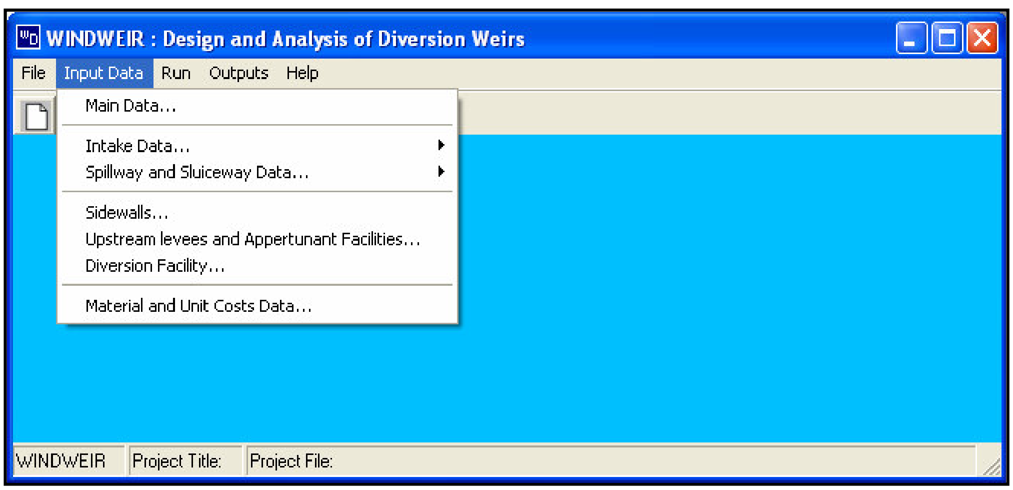


Figure A.4. Menu items related to the input data.

- Main Data : This window groups the input data related to main irrigation canal and the river. Also the flood discharges for various return periods and the corresponding tailwater surface elevations are entered through this window.

- Intake Data : The window which appears after clicking on this menu item deals with the input data related to the design of the intake. This group of data are also subdivided into two such that one of them groups the input data related to the plan view of the intake, and the other one groups the input data related to the profile view of the intake as follows:

  - Plan Geometry : The required input data that are illustrated in the plan view of the intake are entered on this window.

  - Profile Geometry : On this window, the required input data that are illustrated in the profile view of intake are entered. The foundation geometry of the intake is also described on this window. The foundation elevations can be entered by the slab thicknesses or by directly the elevation values. The user selects the desired way by available radio buttons (see Figure A.5).

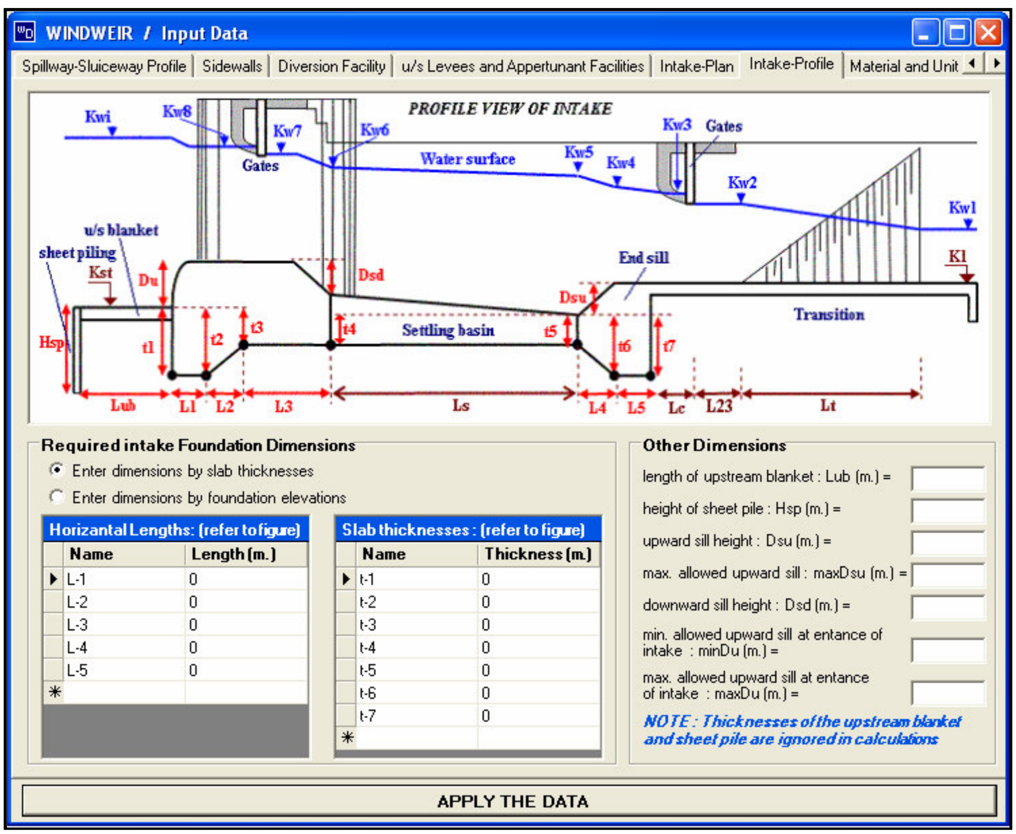


Figure A.5. Input data window for intake profile.

- Spillway and Sluiceway Data : Similar to the input data related to the design of the intake, the input data on spillway and sluiceways are also divided into two sub-groups as cross-section view, and profile view, which are described as follows:

  - Cross-section Geometry : The input data illustrated in the cross-section geometry of the spillway and sluiceways are entered on this window. There is also an option of viewing the plan view of the spillway and sluiceways on this window by clicking the corresponding label on the window. In case of the existence of a bridge over the spillway, which is the default case, the corresponding checkbox is checked in order to enter the input data related to the bridge, such as discharge contraction coefficients due to the bridge piers and abutments, etc. If there is not a bridge over the spillway, the entrance of the bridge data are not allowed by the program (see Figure A.6).

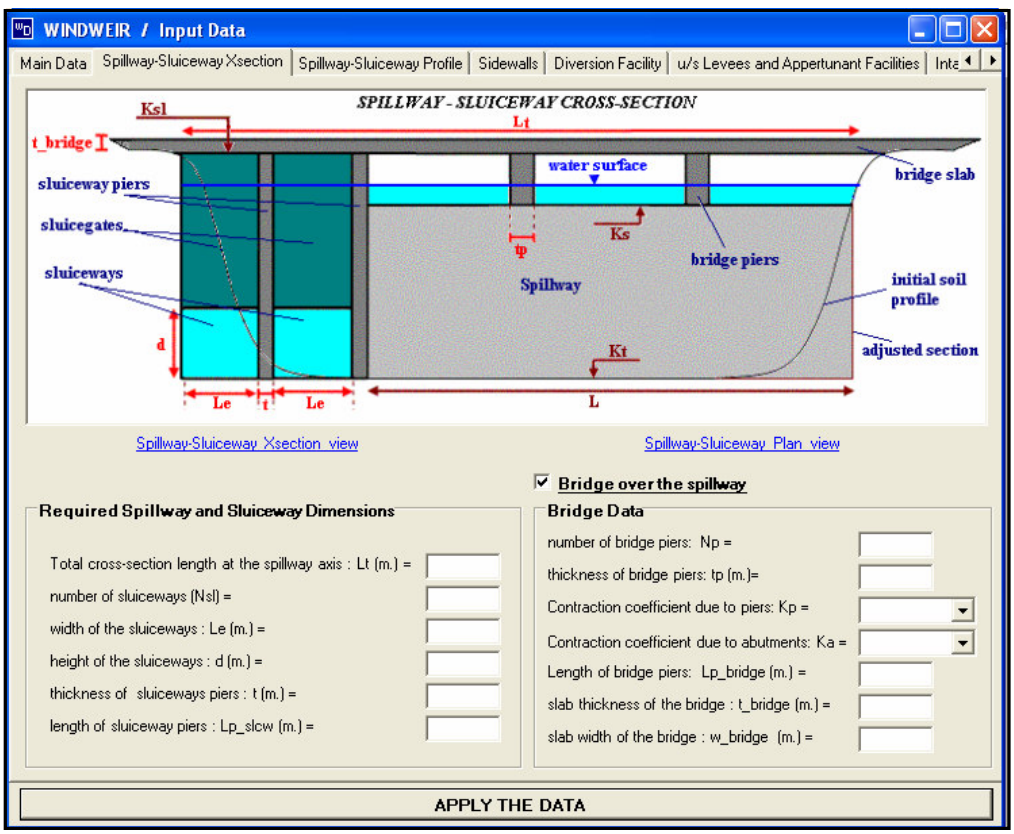


Figure A.6. Input data window for spillway and sluiceway cross section.

- Profile Geometry : The input data illustrated in the profile view of the spillway and sluiceways are entered on this window. Similar to the case of the intake, the foundation geometry can be described by entering the slab thicknesses or the elevation values. The program assumes the same foundation profile for the spillway and sluiceways. However, due to the hydraulic limitations as stated in Chapter 3, these elevations may be different for spillway and sluiceway foundations.

- Sidewalls : This menu item brings the window related to the design of the sidewalls on the screen. All the required data are entered on this window. There is also an option of increasing the bottom width of the retaining wall to satisfy the safety criteria. If this option is selected, the program increases the bottom width until the desired safety is satisfied. In that case, the entered bottom width value is assumed to be the initial value for the iteration. If this option is not selected, then the program does not make any iteration to satisfy the safety criteria. It only reports the result.

- Upstream levees and appurtenant facilities : This menu item brings the window related to the input data for the design of the upstream levees and appurtenant facilities. Input data regarding the design of the ripraps and the flushing pipe are also entered on this window.

- Diversion facility : Input data related to the design of the diversion facility are entered on the window appearing after clicking this menu item. The diversion canal design discharge is selected among the flood discharges, which are entered at the main data window.

- Material and unit cost data : This window contains three groups of data, which are material data, safety criteria, and the unit cost values.

After entering the input data, they must be activated by pressing the button named "APPLY THE DATA". By doing so, the entered data are assigned to the corresponding variables of the program. If the data are not activated, the program will give error during the execution.

A.2.3 Menu Items Related to the Computation

Under the menu item named "Run", there is only one menu item named as "Start Computation". This menu item brings the computation window on the screen. On this window, there are two options for the computation type. The first one is for analyzing the whole diversion weir and the second one is for the optimization of the bottom width at the entrance of the main irrigation canal. The first option is the default one. If it is selected, the computation is started by pressing the button named "START COMPUTATION" (see Figure A.7).

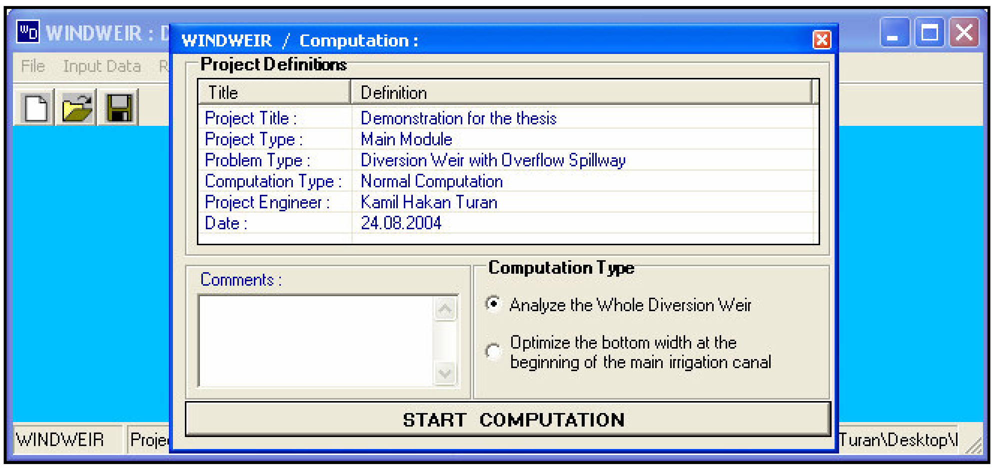


Figure A.7.Window for the selection of the computation type.

During the computation process, a window appears, which shows the computation status by giving appropriate messages (see Figure A.8). If there is an error in the computation, the corresponding error message is also displayed on this window. The end of the computation is understood by the message "COMPUTATION ENDS". This means that computation is performed successfully without any error and the outputs are ready for examining. This window is closed by pressing the button named "CLOSE" and then the main window appears for inspection of the results. This is done through the menu items grouped in the main menu item named "Outputs". Details of these menu items related to outputs are explained in the following section.

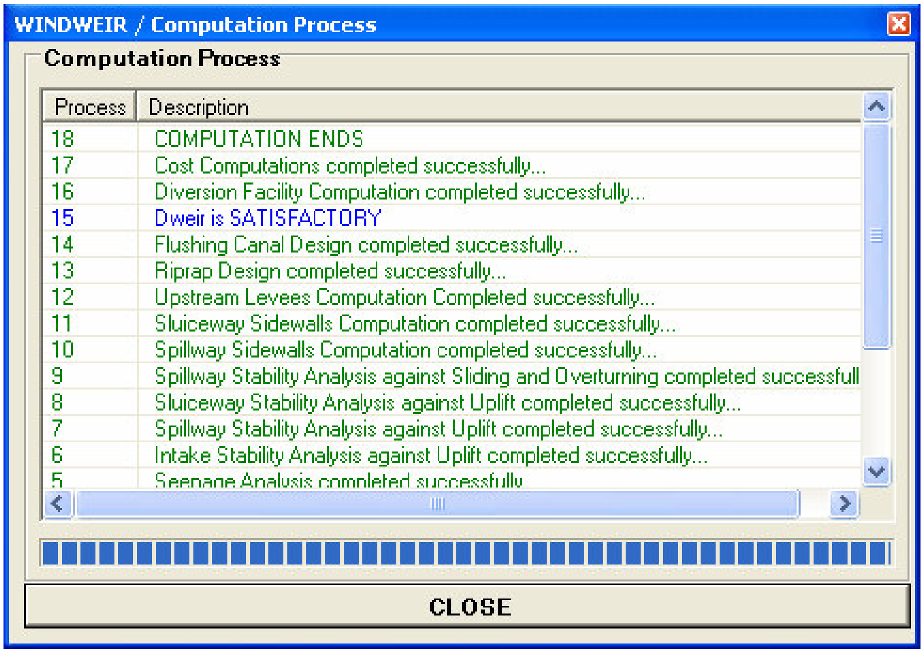


Figure A.8. Window related to the computation processes.

A.2.4 Menu Items Related to the Outputs

Since there are many structural components in a diversion weir, there exists many results related to each component. Therefore, all the results are grouped under the major menu item named "Outputs" to be examined (see Figure A.9).

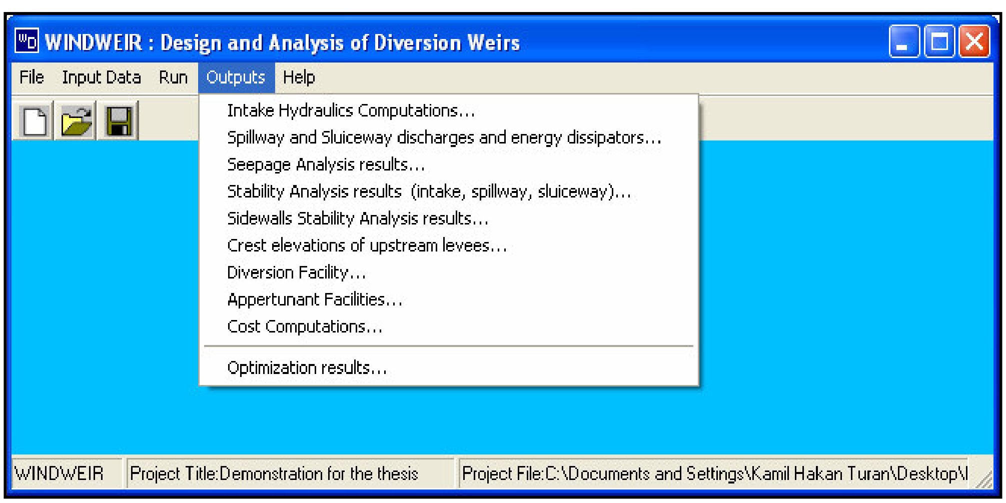


Figure A.9. Menu items related to the outputs.

Each window is brought by these menu items which contain three menu items (see Figure A.10).

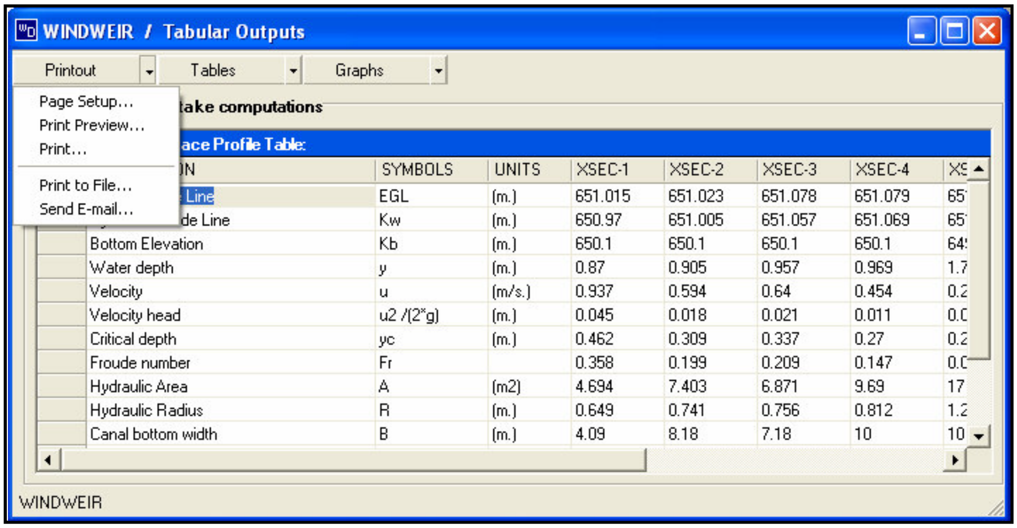


Figure A.10. A typical output window displaying printout options.

- Printout : Under this menu item, there are five sub-menu items related to the print-out capabilities of the program as shown in Figure A.10. They are summarized as follows:
    - Page Setup : This menu item brings a window for changing the page setup values, such as the orientation of the page and the margins, etc.
    - Print Preview : This menu item previews the page to be printed.
    - Print : The window showing the print-out features appears by clicking this menu item. The button named "OK" is pressed on this window to start printing.
    - Print to File : This menu item brings a window for exporting the results to different formats, such as a text file. "File Txt (.*txt)" from the options "Save as type" is selected to export the results to a text file by entering the name and location of the file to be exported. Some additional formats, such as a web page format are also available for exporting the results.

- Send E-mail : By using this menu item, the results can be sent to another user via e-mail.

- Tables : This menu item contains available tabular results of the designed component. Some components may have a single tabular result whereas some may have more than one tabular result. The desired results can be accessed on the same window by selecting the corresponding sub-menu item under this menu (see Figure A.11). All the components have at least one tabular result.

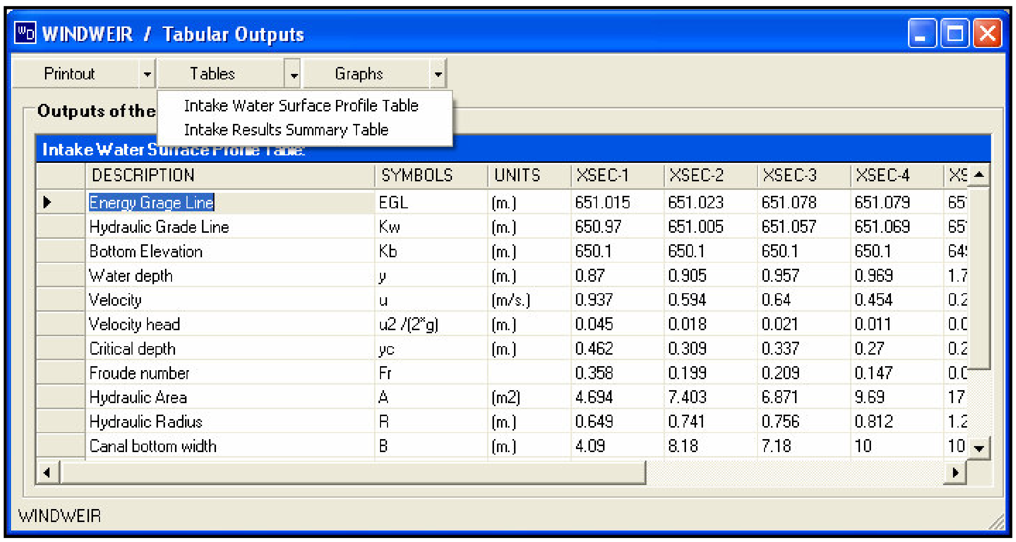


Figure A.11. A typical output window for the selection of an available tabular output.

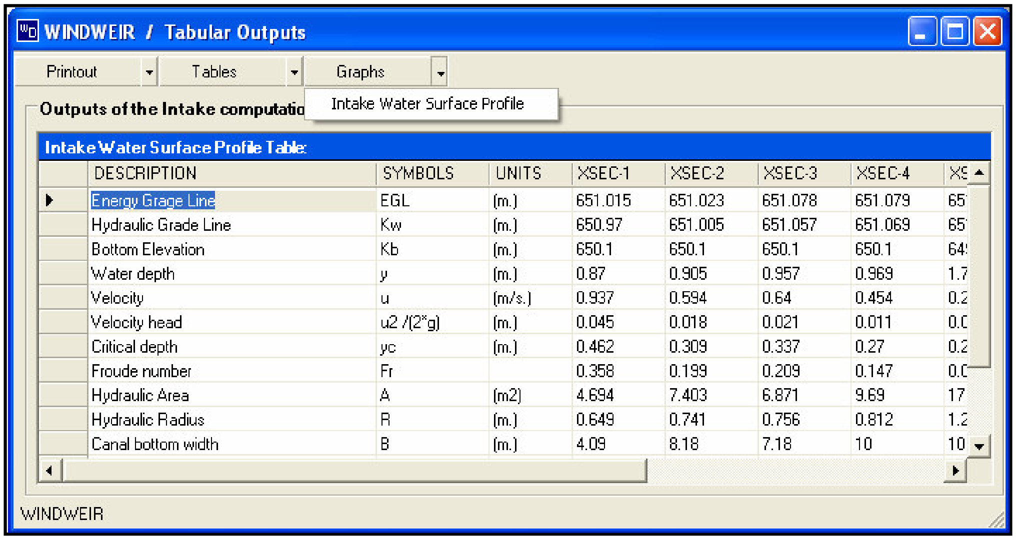
- Graphs : This menu item brings the list of the graphical outputs for the results of the corresponding component. However, all the components do not have a graphical output. In these cases, this menu item becomes unavailable. Figure A.12 shows a typical window for the selection of an available graphical output. When the desired graphical output is selected, a new window displaying the corresponding graphical result appears (see Figure A.13).

In the windows displaying graphical outputs, there are also three menu items:

- Printout : By this menu item, the printout of the graph is obtained.

- Choose Graph : This menu item gives the user to select some portions of the graph or the whole graph.

- Graph Options : Some features of the graph, such as displaying the gridlines, etc., can be modified by this menu item.



DESCRIPTION	SYMBOLS	UNITS	XSEC-1	XSEC-2	XSEC-3	XSEC-4	XS
Energy Grage Line	EGL	(m.)	651.015	651.023	651.078	651.079	65
Hydraulic Grade Line	Kw	(m.)	650.97	651.005	651.057	651.069	65
Bottom Elevation	Kb	(m.)	650.1	650.1	650.1	650.1	64
Water depth	y	(m.)	0.87	0.905	0.957	0.969	1.7
Velocity	u	(m/s.)	0.937	0.594	0.64	0.454	0.2
Velocity head	u2 /(2*g)	(m.)	0.045	0.018	0.021	0.011	0.0
Critical depth	yc	(m.)	0.462	0.309	0.337	0.27	0.2
Froude number	Fr		0.358	0.199	0.209	0.147	0.0
Hydraulic Area	A	(m2)	4.694	7.403	6.871	9.69	17
Hydraulic Radius	R	(m.)	0.649	0.741	0.756	0.812	1.2
Canal bottom width	B	(m.)	4.09	8.18	7.18	10	10

Figure A.12. A typical output window for the selection of an available graphical output.

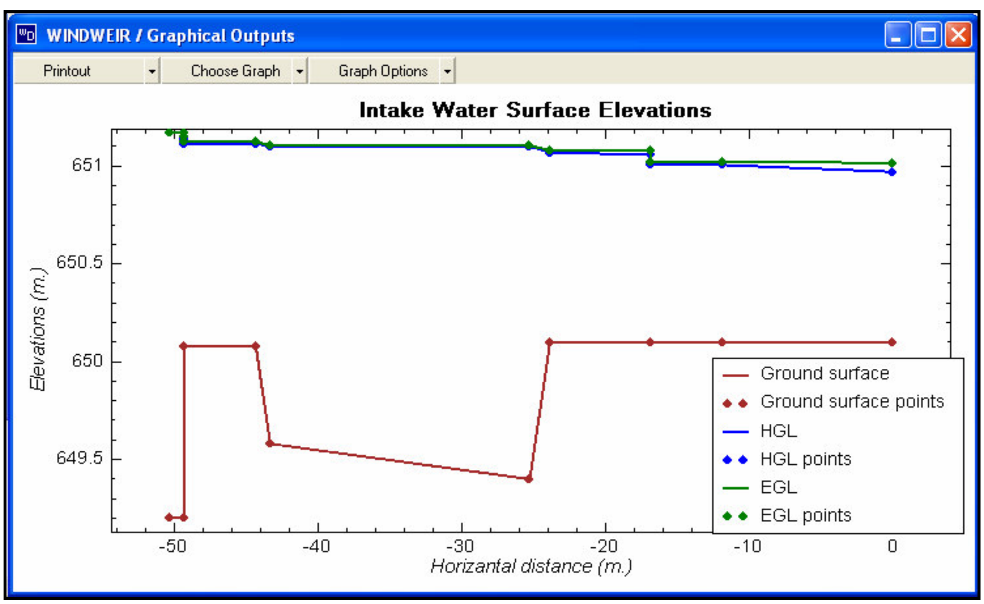


Figure A.13. A typical window displaying an available graphical output.

All the sub-menu items under the major menu item, “Outputs” on the main window of the program give the following outputs:

- Intake Hydraulics Computations,
- Spillway and Sluiceway discharges and energy,
- Seepage Analysis results,
- Stability Analysis results,
- Sidewalls Stability Analysis Results,
- Crest elevation of upstream levees,
- Diversion Facility,
- Appurtenant facilities,
- Cost computations,
- Optimization results.

Menu item, “Optimization results”, is only available if the computation for the minimization of the total cost by optimizing the bottom width at the entrance of the main irrigation canal is performed.

A.2.5 Menu Items Related to the Help

This menu item is used in order to access help and information about the program. Also e-mail address of the developer of the program can be obtained on the window appearing as a result of clicking the sub-menu item, “About” under the major menu item, “Help”. The developer of the program can be reached through this e-mail address for any discussion about the program.

APPENDIX B

SOURCE CODE OF WINDWEIR

```
'*------------------------------------------------------------------------------------------------------------------------*
'|                                 CLASS-1:  Class1.vb                                                                    |
'|                                 (Hydraulic Computations)                                                               |
'|                                 (This is the core of the program)                                                      |
'*------------------------------------------------------------------------------------------------------------------------*
Imports System.Math
Imports dweir_code.General_Hydraulic_Functions
Imports dweir_code.General_Hydraulic_Functions.OCH_func
Imports dweir_code.Appurtenant_fac
Imports dweir_code.cost_computations
Imports dweir_code.intake_design
Imports dweir_code.levees_and_diversion
Imports dweir_code.splw_slcw_design
Imports dweir_code.stability_analysis
Imports dweir_code.computations.error_hand
'*************************************************************
'*   General note: all input data classes were implemented             *
'*   with copy constructors; however other classes were                *
'*   implemented with copy constructors only when needed.              *
'*************************************************************
Namespace General_Hydraulic_Functions
#Region "Data structures"
    'computation information structure
    <Serializable()> Public Class computation_information  'in order to give information about computation
        Public percent As Single
        Public message As String
        Public state As Byte  '0:normal comp, 1:error 2:warning 3:accepted (these will match some colors)
        Public Sub New(ByVal inp As computation_information) 'copy constructor
            Me.percent = inp.percent
            Me.message = inp.message
            Me.state = inp.state
        End Sub
        Public Sub New()
        End Sub
    End Class
    'stilling basin data for determining details of stilling basin type
    <Serializable()> Public Class stillingbasin
        Public type As String
        Public L As Single
        Public delta As Single  'delta is same as delta_usbr; delta is the sill height found from energy equation
(min sill height)
        Public delta_usbr As Single   'delta_usbr is sill heigh proposed by USBR, if deltausbr>delta delta should
be used (because delta is theoretical min value
        Public B As Single
        Public y1 As Single
        Public y2 As Single
        Public y3 As Single
        Public Fr1 As Single
        Public u1 As Single
        Public TW As Single
        Public n_chute_blocks As Integer
        Public n_baffle_piers As Integer
        Public vol_chute_blocks As Single
```

```
        Public vol_baffle_piers As Single
        Public Sub New(ByVal inp As stillingbasin) 'copy constr
            Me.type = inp.type
            Me.L = inp.L
            Me.delta = inp.delta
            Me.B = inp.B
            Me.delta_usbr = inp.delta_usbr
            Me.Fr1 = inp.Fr1
            Me.n_baffle_piers = inp.n_baffle_piers
            Me.n_chute_blocks = inp.n_chute_blocks
            Me.TW = inp.TW
            Me.u1 = inp.u1
            Me.vol_baffle_piers = inp.vol_baffle_piers
            Me.vol_chute_blocks = inp.vol_chute_blocks
            Me.y1 = inp.y1
            Me.y2 = inp.y2
            Me.y3 = inp.y3
        End Sub
        Public Sub New()
        End Sub
    End Class
    'point decleration for structure determining
    <Serializable()> Public Class c_point  'coordinate point (in order to not distinguish with graphics point)
        Public x As Single
        Public y As Single
        Sub New(ByVal xx As Single, ByVal yy As Single)
            x = xx
            y = yy
        End Sub
        Public Sub New(ByVal inp As c_point) 'copy constr
            Me.x = inp.x
            Me.y = inp.y
        End Sub
        Public Sub New()
        End Sub
    End Class
#End Region
#Region "Classes"
    <Serializable()> Public Class OCH_func  'declared as public in order to access the module members

'**************************************************************************************************
'* MODULE DECLERATION: OPEN CHANNEL HYDRAULICS CALCULATIONS                                       *
'**************************************************************************************************
'* EXPLANATION: -These functions are for "Open Channel Hydraulic Calculations"                    *
 '*             -These functions are for "Trapezoidal Channels"                                   *
 '*              (They can be simply used for "Rectangular" and "Triangular" channels             *
 '*                  by giving "B" and "mh" proper values")                                       *
 '*             -The ground slope(teta) is assumed to be less than 6 degrees.                     *
'*              (if teta<=6 degrees cos^2>=0.99 meaning that pressure distribution can be         *
'*               assumed as hydrostatic.)                                                         *
'*              (P=gamma*y ---> y:water depth (perpendicular to the canal(ground) surface)        *
'*************************************************************************************************
'* WRITTEN BY: KAMIL HAKAN TURAN                                                                 *
'* DATE:13.08.2003                                                                               *
'*************************************************************************************************
        Public Const g = 9.81 'm/s2
        Public Const nu = 10 ^ -6  'm2/s
        Public Const pwater = 1000 'kg/m3
        'max iteration limits
        Public Shared max_iter = 500
        Public Shared Function f_T(ByVal B As Single, ByVal mh As Single, ByVal y As Single) As Single
```

```
            Return (B + 2 * (mh * y))
        End Function
        Public Shared Function f_A(ByVal B As Single, ByVal mh As Single, ByVal y As Single) As Single
            Return ((B + f_T(B, mh, y)) / 2 * y)
        End Function
        Public Shared Function f_P(ByVal B As Single, ByVal mh As Single, ByVal y As Single) As Single
            Return (B + 2 * (((mh * y) ^ 2 + y ^ 2) ^ 0.5))
        End Function
        Public Shared Function f_R(ByVal B As Single, ByVal mh As Single, ByVal y As Single) As Single
            Return (f_A(B, mh, y) / f_P(B, mh, y))
        End Function
        Public Shared Function f_Dy(ByVal B As Single, ByVal mh As Single, ByVal y As Single) As Single
            Return (f_A(B, mh, y) / f_T(B, mh, y))
        End Function
        Public Shared Function f_Qmann(ByVal B As Single, ByVal mh As Single, ByVal y As Single, ByVal n
As Single, ByVal So As Single) As Single
            Return (f_A(B, mh, y) / n * (f_R(B, mh, y) ^ (2 / 3)) * (So ^ 0.5))
        End Function
        Public Shared Function f_flow(ByVal Fr As Single) As String
            If Round(Fr, 2) < 1 Then
                Return "subcritical"
            ElseIf Round(Fr, 2) = 1 Then
                Return "critical"
            Else
                Return "supercritical"
            End If
        End Function
        Public Overloads Shared Function f_u(ByVal Q As Single, ByVal A As Single) As Single
            Return (Q / A)
        End Function
        Public Overloads Shared Function f_u(ByVal Q As Single, ByVal y As Single, ByVal mh As Single,
ByVal B As Single) As Single
            Return (Q / f_A(B, mh, y))
        End Function
        Public Overloads Shared Function f_velhead(ByVal u As Single) As Single
            Return u ^ 2 / (2 * g)
        End Function
        Public Overloads Shared Function f_velhead(ByVal Q As Single, ByVal y As Single, ByVal mh As
Single, ByVal B As Single) As Single
            Return (f_u(Q, y, mh, B) ^ 2) / (2 * g)
        End Function
        Public Shared Function f_HGL(ByVal Kb As Single, ByVal y As Single) As Single
            Return (Kb + y)
        End Function
        Public Shared Function f_EGL(ByVal Kb As Single, ByVal u As Single, ByVal y As Single) As Single
            Return (Kb + y + u ^ 2 / (2 * g))
        End Function
        Public Overloads Shared Function f_Fr(ByVal u As Single, ByVal D As Single) As Single
            Return (u / (g * D) ^ 0.5)
        End Function
        Public Overloads Shared Function f_Fr(ByVal Q As Single, ByVal y As Single, ByVal mh As Single,
ByVal B As Single) As Single
            Return (f_u(Q, y, mh, B) / (g * f_Dy(B, mh, y)) ^ 0.5)
        End Function
        Public Overloads Shared Function f_Sf(ByVal Q As Single, ByVal n As Single, ByVal A As Single,
ByVal R As Single) As Single
            Return ((Q * n) / (A * (R ^ (2 / 3)))) ^ 2
        End Function
        Public Overloads Shared Function f_Sf(ByVal Q As Single, ByVal y As Single, ByVal B As Single,
ByVal mh As Single, ByVal n As Single) As Single
            Return ((Q * n) / (f_A(B, mh, y) * (f_R(B, mh, y) ^ (2 / 3)))) ^ 2
```

```
    End Function
    Public Overloads Shared Function f_ynormal(ByVal Q As Single, ByVal B As Single, ByVal mh As Single, ByVal n As Single, ByVal Sf As Single) As Single
        'Secant method is used to iterate the normal depth.
        Dim y0, y1, temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        y0 = 1000
        y1 = 990
        Do Until Abs(y1 - y0) <= 0.001
            delta0 = Q - f_Qmann(B, mh, y0, n, Sf)
            delta1 = Q - f_Qmann(B, mh, y1, n, Sf)
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = Round(y1, 3)
            y1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        Return y1
    End Function
    Public Overloads Shared Function f_ynormal(ByVal Q As Single, ByVal B As Single, ByVal mh As Single, ByVal n As Single, ByVal Sf As Single, ByVal y0 As Single, ByVal y1 As Single, ByVal epsilon As Single) As Single
        'Secant method is used to iterate the normal depth.
        Dim temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        Do Until Abs(y1 - y0) <= epsilon
            delta0 = Q - f_Qmann(B, mh, y0, n, Sf)
            delta1 = Q - f_Qmann(B, mh, y1, n, Sf)
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = y1
            y1 = temp
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        Return Round(y1, 3)
    End Function
    Public Overloads Shared Function f_ycritical(ByVal Q As Single, ByVal B As Single, ByVal mh As Single) As Single
        'Secant method is used to iterate the critical depth.
        Dim y0, y1, temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        y0 = 1000
        y1 = 990
        Do Until Abs(y1 - y0) <= 0.001
            delta0 = Q ^ 2 * f_T(B, mh, y0) - g * f_A(B, mh, y0) ^ 3
            delta1 = Q ^ 2 * f_T(B, mh, y1) - g * f_A(B, mh, y1) ^ 3
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = Round(y1, 3)
            y1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
```

```
            Return y1
        End Function
        Public Overloads Shared Function f_ycritical(ByVal Q As Single, ByVal B As Single, ByVal mh As
Single, ByVal y0 As Single, ByVal y1 As Single, ByVal epsilon As Single) As Single
            'Secant method is used to iterate the critical depth.
            Dim temp As Single
            Dim delta0, delta1 As Single
            Dim i As Integer = 0
            Do Until Abs(y1 - y0) <= epsilon
                delta0 = Q ^ 2 * f_T(B, mh, y0) - g * f_A(B, mh, y0) ^ 3
                delta1 = Q ^ 2 * f_T(B, mh, y1) - g * f_A(B, mh, y1) ^ 3
                temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
                y0 = y1
                y1 = temp
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            Return Round(y1, 3)
        End Function
        Public Shared Function f_Sfc(ByVal Q As Single, ByVal B As Single, ByVal mh As Single, ByVal n As
Single) As Single
            Return ((Q * n) / (f_A(B, mh, f_ycritical(Q, B, mh)) * (f_R(B, mh, f_ycritical(Q, B, mh)) ^ (2 / 3)))) ^
2
        End Function
        Public Overloads Shared Function f_Es(ByVal Q As Single, ByVal y As Single, ByVal mh As Single,
ByVal B As Single) As Single
            Return y + ((f_u(Q, y, mh, B)) ^ 2) / (2 * g)
        End Function
        Public Overloads Shared Function f_Es(ByVal Q As Single, ByVal y As Single, ByVal u As Single) As
Single
            Return y + (u ^ 2) / (2 * g)
        End Function
        Public Overloads Shared Function f_Esmin(ByVal Q As Single, ByVal B As Single, ByVal mh As
Single) As Single
            Return f_ycritical(Q, B, mh) + f_Dy(B, mh, f_ycritical(Q, B, mh)) / 2
        End Function
        Public Overloads Shared Function f_Esmin(ByVal ycritical As Single, ByVal Dycritical As Single) As
Single
            Return ycritical + Dycritical / 2
        End Function
        Public Overloads Shared Function f_yalternate(ByVal Es As Single, ByVal Q As Single, ByVal B As
Single, ByVal mh As Single) As Single() 'returns an array
            Dim yalternate(1) As Single
            'Secant method is used to iterate the critical depth.
            Dim y0, y1, temp As Single
            Dim delta0, delta1 As Single
            Dim i As Integer = 0
            y0 = 1000
            y1 = 990
            Do Until Abs(y1 - y0) <= 0.001
                delta0 = Es - f_Es(Q, y0, mh, B)
                delta1 = Es - f_Es(Q, y1, mh, B)
                temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
                y0 = Round(y1, 3)
                y1 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
```

```
            Loop
            yalternate(0) = y1 'subcritical depth
            'for the second alternate depth (second root of the equation)
            'initialize the variables again
            i = 0
            y0 = 0.01
            y1 = 0.005

            Do Until Abs(y1 - y0) <= 0.001
                delta0 = Es - f_Es(Q, y0, mh, B)
                delta1 = Es - f_Es(Q, y1, mh, B)
                temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
                y0 = Round(y1, 3)
                y1 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            yalternate(1) = y1 'supercritical depth
            Return yalternate
        End Function
        Public Overloads Shared Function f_yalternate(ByVal Es As Single, ByVal Q As Single, ByVal B As
Single, ByVal mh As Single, ByVal y00 As Single, ByVal y10 As Single, ByVal y01 As Single, ByVal y11
As Single, ByVal epsilon0 As Single, ByVal epsilon1 As Single) As Single() 'returns an array
            Dim yalternate(1) As Single
            'Secant method is used to iterate the critical depth.
            Dim temp As Single
            Dim delta0, delta1 As Single
            Dim i As Integer = 0
            Do Until Abs(y10 - y00) <= epsilon0
                delta0 = Es - f_Es(Q, y00, mh, B)
                delta1 = Es - f_Es(Q, y10, mh, B)
                temp = y10 - (delta1 * (y10 - y00) / (delta1 - delta0))
                y00 = Round(y10, 3)
                y10 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            yalternate(0) = y10
            'for the second alternate depth (second root of the equation)
            'initialize the variables again
            i = 0
            y00 = 0.01
            y11 = 0.005
            Do Until Abs(y10 - y00) <= epsilon1
                delta0 = Es - f_Es(Q, y01, mh, B)
                delta1 = Es - f_Es(Q, y11, mh, B)
                temp = y11 - (delta1 * (y11 - y01) / (delta1 - delta0))
                y01 = Round(y11, 3)
                y11 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            yalternate(1) = y11
            Return yalternate
        End Function
```

```
        Public Shared Function f_ycentroid(ByVal B As Single, ByVal mh As Single, ByVal y As Single) As
Single
            Return (2 * (y ^ 2 * mh / 2 * y / 3) + B * y * y / 2) / (B * y + y * mh * y)
        End Function
        Public Overloads Shared Function f_Fs(ByVal ycentroid As Single, ByVal Q As Single, ByVal A As
Single) As Single

            Return (ycentroid * A + Q ^ 2 / (g * A))
        End Function
        Public Overloads Shared Function f_Fs(ByVal Q As Single, ByVal B As Single, ByVal mh As Single,
ByVal y As Single) As Single
            Return (f_ycentroid(B, mh, y) * f_A(B, mh, y)) + Q ^ 2 / (g * f_A(B, mh, y))
        End Function
        Public Overloads Shared Function f_Re(ByVal u As Single, ByVal R As Single) As Single
            Return u * R / nu
        End Function
        Public Overloads Shared Function f_Re(ByVal u As Single, ByVal B As Single, ByVal mh As Single,
ByVal y As Single) As Single
            Return u * f_R(B, mh, y) / nu
        End Function
        Public Overloads Shared Function f_Kw1(ByVal Kw0 As Single, ByVal hl As Single, ByVal u0 As
Single, ByVal u1 As Single) As Single
            Return Kw0 + f_velhead(u0) + hl - f_velhead(u1)
        End Function
        Public Overloads Shared Function f_Kw1(ByVal Q As Single, ByVal Kw0 As Single, ByVal hl As
Single, ByVal mh0 As Single, ByVal B0 As Single, ByVal mh1 As Single, ByVal B1 As Single, ByVal y0 As
Single, ByVal y1 As Single) As Single
            Return (Kw0 + f_velhead(f_u(Q, y0, mh0, B0)) + hl - f_velhead(f_u(Q, y1, mh1, B1)))
        End Function
        'hydraulic jump: Fs1=Fs2
        Public Overloads Shared Function f_yconjugate(ByVal y As Single, ByVal B As Single, ByVal mh As
Single, ByVal Q As Single) As Single
            Dim Fs1 As Single = f_Fs(Q, B, mh, y)
            'Secant method is used to iterate the normal depth.
            Dim y0, y1, temp As Single
            Dim delta0, delta1 As Single
            Dim i As Integer = 0
            y0 = 1000
            y1 = 990
            Do Until Abs(y1 - y0) <= 0.001
                delta0 = Fs1 - f_Fs(Q, B, mh, y0)
                delta1 = Fs1 - f_Fs(Q, B, mh, y1)
                temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
                y0 = Round(y1, 3)
                y1 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            Return y1
        End Function
        Public Overloads Shared Function f_yconjugate(ByVal y As Single, ByVal B As Single, ByVal mh As
Single, ByVal Q As Single, ByVal y0 As Single, ByVal y1 As Single, ByVal epsilon As Single) As Single
            Dim Fs1 As Single = f_Fs(Q, B, mh, y)
            'Secant method is used to iterate the normal depth.
            Dim temp As Single
            Dim delta0, delta1 As Single
            Dim i As Integer = 0
            Do Until Abs(y1 - y0) <= epsilon
                delta0 = Fs1 - f_Fs(Q, B, mh, y0)
```

```
            delta1 = Fs1 - f_Fs(Q, B, mh, y1)
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = Round(y1, 3)
            y1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        Return y1
    End Function
    Public Overloads Shared Function f_hl_hydjump(ByVal Q As Single, ByVal y1 As Single, ByVal y2 As
Single, ByVal mh As Single, ByVal B As Single) As Single
        Return f_Es(Q, y1, mh, B) - f_Es(Q, y2, mh, B)
    End Function
    Public Overloads Shared Function f_hl_hydjump(ByVal Q As Single, ByVal y As Single, ByVal mh As
Single, ByVal B As Single) As Single
        Dim y2 As Single = f_yconjugate(y, B, mh, Q)
        Return f_Es(Q, y, mh, B) - f_Es(Q, y2, mh, B)
    End Function
    'conjugate depths calculation from head loss
    Public Shared Function f_yconjugatehl(ByVal hl As Single, ByVal B As Single, ByVal mh As Single,
ByVal Q As Single) As Single()
        Dim yconjugate(1) As Single
        'Secant method is used to iterate the normal depth.
        Dim y0, y1, temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        y0 = 0.01
        y1 = 0.005
        Do Until Abs(y1 - y0) <= 0.001
            delta0 = hl - f_hl_hydjump(Q, y0, mh, B)
            delta1 = hl - f_hl_hydjump(Q, y1, mh, B)
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = Round(y1, 3)
            y1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        yconjugate(0) = y1
        yconjugate(1) = f_yconjugate(yconjugate(0), B, mh, Q)
        Return yconjugate
    End Function
    'some specific functions
    Public Shared Function f_y_hl_type1(ByVal Q As Single, ByVal B1 As Single, ByVal mh1 As Single,
ByVal coeff As Single, ByVal velhead0 As Single, ByVal Es0 As Single) As Single

'*******************************************************************************
'* WHEN TO USE THE FUNCTION:                                                   *
'* this is a depth calculation from a typical energy equilibrium with head loss *
'* type of head loss function: hl=C*(u0^2-u1^2)/(2*g)                          *
'*******************************************************************************
        'Secant method is used to iterate the depth y1
        Dim y0, y1, temp As Single
        Dim delta0, delta1 As Single
        Dim hl As Single
        y0 = 1000
        y1 = 990
        Dim i As Integer = 0
```

```
        Do Until Abs(y1 - y0) <= 0.001
            hl = coeff * (velhead0 - f_velhead(Q, y0, mh1, B1))
            delta0 = Es0 + hl - f_Es(Q, y0, 0, B1)
            hl = coeff * (velhead0 - f_velhead(Q, y1, mh1, B1))
            delta1 = Es0 + hl - f_Es(Q, y1, 0, B1)
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = Round(y1, 3)
            y1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        Return y1
    End Function
    Public Shared Function f_delta_He(ByVal Q As Single, ByVal B As Single, ByVal y0 As Single) As
Single
        'headloss over a sill: Q=2.88*Bs*(2/3*delta_He^(3/2)+y*delta_He^(0.5))
        ' secant method is used to find delta_He
        Dim delta_He0, delta_He1, temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        '- because of the fact that delta_He must be positive, it converges from point zero
        delta_He0 = 0.005
        delta_He1 = 0.001
        Do Until Abs(delta_He1 - delta_He0) <= 0.001
            delta0 = Q - 2.88 * B * (2 / 3 * (delta_He0 ^ 1.5) + y0 * (delta_He0 ^ 0.5))
            delta1 = Q - 2.88 * B * (2 / 3 * (delta_He1 ^ 1.5) + y0 * (delta_He1 ^ 0.5))
            temp = delta_He1 - (delta1 * (delta_He1 - delta_He0) / (delta1 - delta0))
            delta_He0 = Round(delta_He1, 3)
            delta_He1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        Return delta_He1
    End Function
    Public Shared Function f_Ls(ByVal Kv As Single, ByVal lamda As Single, ByVal r As Single, ByVal y
As Single, ByVal us As Single, ByVal ustar As Single) As Single
        Return (-6 * (us / ustar) * y * Log((1 - r), E) / (Kv * lamda))
    End Function
    Public Overloads Shared Function f_ustar(ByVal R As Single, ByVal So As Single) As Single
        Return (g * R * So) ^ 0.5
    End Function
    Public Overloads Shared Function f_ustar(ByVal y As Single, ByVal B As Single, ByVal mh As Single,
ByVal So As Single) As Single
        Return (g * f_R(B, mh, y) * So) ^ 0.5
    End Function
    'critical sher velocity
    Public Shared Function f_ustarc(ByVal delta As Single, ByVal Dm As Single) As Single
        Dim Dstar As Single
        Dstar = ((delta * g * Dm ^ 3) / (nu ^ 2)) ^ (1 / 3)
        If (Dstar / 2.15) < 1 Then
            Return ((Dstar / 2.15) * nu / Dm)
        ElseIf (((Dstar / 2.5) ^ (5 / 4)) >= 1 And ((Dstar / 2.5) ^ (5 / 4)) <= 10) Then
            Return ((Dstar / 2.5) ^ (5 / 4)) * nu / Dm
        Else
            Return ((Dstar / 3.8) ^ (8 / 5)) * nu / Dm
        End If
    End Function
```

```
    Public Shared Function f_beta(ByVal Wf As Single, ByVal Kv As Single, ByVal ustar As Single) As
Single
        Return (Wf / (Kv * ustar))
    End Function
    Public Overloads Shared Function f_lamda(ByVal beta As Single) As Single
        Return (8.87 * beta ^ 1.17)
    End Function
    Public Overloads Shared Function f_lamda(ByVal Wf As Single, ByVal Kv As Single, ByVal ustar As
Single) As Single
        Return (8.87 * f_beta(Wf, Kv, ustar) ^ 1.17)
    End Function
    Public Shared Function f_Wf(ByVal Dm As Single) As Single
        Dim i As Integer = 0
        Dim Wf_m(,) As Single = {{0.15 / 1000, 14.8 / 1000}, {0.3 / 1000, 36.1 / 1000}, {0.4 / 1000, 50 /
1000}, _
        {0.5 / 1000, 64 / 1000}, {0.6 / 1000, 76.4 / 1000}, {0.8 / 1000, 99 / 1000}, {0.9 / 1000, 110 / 1000}, {1
/ 1000, 121 / 1000}, _
        {1.2 / 1000, 137.3 / 1000}, {1.5 / 1000, 166 / 1000}}
        If Dm < 0.00015 Then 'Dm<0.15 mm
            Return (663 * Dm ^ 2)
        ElseIf Dm > 0.0015 Then  'Dm>1.5 mm
            Return (134.5 * Dm ^ 0.5)
        Else
            Do Until (Wf_m(i, 0) >= Dm)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            Return (Wf_m(i, 1) - (Wf_m(i, 0) - Dm) * (Wf_m(i, 1) - Wf_m(i - 1, 1)) / (Wf_m(i, 0) - Wf_m(i - 1,
0)))
        End If
    End Function
    Public Shared Function f_poly(ByVal F As Single, ByVal c0 As Single, ByVal p0 As Single, ByVal c1
As Single, ByVal p1 As Single, ByVal c2 As Single, ByVal p2 As Single, ByVal c3 As Single, ByVal p3 As
Single, ByVal c4 As Single, ByVal p4 As Single) As Single()
        'roots of a genereral polynomial function
        'F(y)=c0*y^p0+c1*y^p1+c2*y^p2+c3*y^p3+c4*y^p4
        'secant method is used to find the roots
        Dim yresult(1) As Single
        Dim y0, y1, temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        y0 = 1000
        y1 = 990
        Do Until Abs(y1 - y0) <= 0.001
            delta0 = F - (c0 * (y0 ^ c0) + c1 * (y0 ^ c1) + c2 * (y0 ^ c2) + c3 * (y0 ^ c3) + c4 * (y0 ^ c4))
            delta1 = F - (c0 * (y1 ^ c0) + c1 * (y1 ^ c1) + c2 * (y1 ^ c2) + c3 * (y1 ^ c3) + c4 * (y1 ^ c4))
            temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
            y0 = Round(y1, 3)
            y1 = Round(temp, 3)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
        Loop
        yresult(0) = y1 'first root (subcritical depth)
        'for the second alternate depth (second root of the equation)
        'initialize the variables again
        i = 0
        y0 = 0.01
```

```
            y1 = 0.005
            Do Until Abs(y1 - y0) <= 0.001
                delta0 = F - (c0 * (y0 ^ c0) + c1 * (y0 ^ c1) + c2 * (y0 ^ c2) + c3 * (y0 ^ c3) + c4 * (y0 ^ c4))
                delta1 = F - (c0 * (y1 ^ c0) + c1 * (y1 ^ c1) + c2 * (y1 ^ c2) + c3 * (y1 ^ c3) + c4 * (y1 ^ c4))
                temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
                y0 = Round(y1, 3)
                y1 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            yresult(1) = y1 'second root (subcritical depth)
            Return yresult
        End Function
        Public Shared Function f_chocking_test(ByVal Q As Single, ByVal y0 As Single, ByVal mh As Single,
ByVal B As Single) As Boolean
            If f_Es(Q, y0, mh, B) < f_Esmin(Q, B, mh) Then
                Return False
            Else
                Return True
            End If
        End Function
        Public Shared Function f_chocking_dz_max(ByVal Q As Single, ByVal y0 As Single, ByVal mh As
Single, ByVal B As Single) As Single
            'only an upward step causes discontinuity (no other section properties changes)
            'in this case y1 becomes critical depth, because energy reduces to min energy
            Return (f_Es(Q, y0, mh, B) - f_Esmin(Q, B, mh))
        End Function
        Public Shared Function f_chocking_B_min(ByVal Q As Single, ByVal mh As Single, ByVal y0 As
Single, ByVal B As Single) As Single
            'only bottom with decrease causes discontinuity (no other section properties changes)
            'secant method is used to find B
            Dim E0 As Single = f_Es(Q, y0, mh, B)
            Dim B0, B1, temp As Single
            Dim delta0, delta1 As Single
            Dim i As Integer = 0
            B0 = 0.01
            B1 = 0.005
            Do Until Abs(B1 - B0) <= 0.001
                delta0 = E0 - f_Esmin(Q, B0, mh)
                delta1 = E0 - f_Esmin(Q, B1, mh)
                temp = B1 - (delta1 * (B1 - B0) / (delta1 - delta0))
                B0 = Round(B1, 3)
                B1 = Round(temp, 3)
                i += 1
                If i >= max_iter Then
                    Exit Do
                End If
            Loop
            Return B1
        End Function
        Delegate Function f_type1(ByVal arg1 As Single) As Single
        Delegate Function f_type2(ByVal arg1 As Single, ByVal arg2 As Single) As Single
        Delegate Function f_type3(ByVal arg1 As Single, ByVal arg2 As Single, ByVal arg3 As Single) As
Single
        Delegate Function f_type4(ByVal arg1 As Single, ByVal arg2 As Single, ByVal arg3 As Single, ByVal
arg4 As Single) As Single
        Delegate Function f_type5(ByVal arg1 As Single, ByVal arg2 As Single, ByVal arg3 As Single, ByVal
arg4 As Single, ByVal arg5 As Single) As Single
```

```
Public Shared Function f_implicite_root(ByVal fconst As Single, ByVal f1 As f_type1, ByVal f2 As
f_type2, ByVal f3 As f_type3, ByVal f4 As f_type4, ByVal f5 As f_type5, ByVal c1 As Single, ByVal c2 As
Single, ByVal c3 As Single, ByVal c4 As Single, ByVal c5 As Single, ByVal uargno2 As Byte, ByVal
uargno3 As Byte, ByVal uargno4 As Byte, ByVal uargno5 As Byte, ByVal ParamArray args() As Single) As
Single

'**********************************************************************************
'* EXPLANATION: Implicite function solver by taking function arguments            *
'*             Argument types are function because of flexibility in use of the    *
'*             function (in order to make function as a general solver)            *
'* NOTES: in order to use functions as arguments "Delegates(function pointers)"  were used.  *
'*       5 types of functions were used; f_type1, f_type2,.....                    *
'*       In delegate names, f_typeX; X indicares the no.of arguments of the func.  *
'*       Paramarray args(); are for the arguments of the delegates used in function *
'*       "uargno" are for the unkown parameter which is to be found.In order to    *
'*        know where the unknown parameter is placed as the argument of the original *
'*        function, this argument was used.It is the place of the unknown parameter *
'*        in the original function's argument list.                                *
'**********************************************************************************
        'Secant method is used to iterate the depth.
        Dim y0, y1, temp As Single
        Dim delta0, delta1 As Single
        Dim i As Integer = 0
        y0 = 1000
        y1 = 990
        Do Until Abs(y1 - y0) <= 0.001
            delta0 = fconst
            delta1 = fconst
            If c1 <> 0 Then
                delta0 += c1 * f1.Invoke(y0)
                delta1 += c1 * f1.Invoke(y1)
            End If
            If c2 <> 0 Then
                Select Case uargno2
                    Case 1
                        delta0 += c2 * f2.Invoke(y0, args(0))
                        delta1 += c2 * f2.Invoke(y1, args(0))
                    Case 2
                        delta0 += c2 * f2.Invoke(args(0), y0)
                        delta1 += c2 * f2.Invoke(args(0), y1)
                End Select
            End If
            If c3 <> 0 Then
                Select Case uargno3
                    Case 1
                        delta0 += c3 * f3.Invoke(y0, args(1), args(2))
                        delta1 += c3 * f3.Invoke(y1, args(1), args(2))
                    Case 2
                        delta0 += c3 * f3.Invoke(args(1), y0, args(2))
                        delta1 += c3 * f3.Invoke(args(1), y1, args(2))
                    Case 3
                        delta0 += c3 * f3.Invoke(args(1), args(2), y0)
                        delta1 += c3 * f3.Invoke(args(1), args(2), y1)
                End Select
            End If
            If c4 <> 0 Then
                Select Case uargno4
                    Case 1
                        delta0 += c4 * f4.Invoke(y0, args(3), args(4), args(5))
                        delta1 += c4 * f4.Invoke(y1, args(3), args(4), args(5))
```

```
                Case 2

                    delta0 += c4 * f4.Invoke(args(3), y0, args(4), args(5))
                    delta1 += c4 * f4.Invoke(args(3), y1, args(4), args(5))
                Case 3
                    delta0 += c4 * f4.Invoke(args(3), args(4), y0, args(5))
                    delta1 += c4 * f4.Invoke(args(3), args(4), y1, args(5))
                Case 4
                    delta0 += c4 * f4.Invoke(args(3), args(4), args(5), y0)
                    delta1 += c4 * f4.Invoke(args(3), args(4), args(5), y1)
            End Select
        End If
        If c5 <> 0 Then
            Select Case uargno5
                Case 1
                    delta0 += c5 * f5.Invoke(y0, args(6), args(7), args(8), args(9))
                    delta1 += c5 * f5.Invoke(y1, args(6), args(7), args(8), args(9))
                Case 2
                    delta0 += c5 * f5.Invoke(args(6), y0, args(7), args(8), args(9))
                    delta1 += c5 * f5.Invoke(args(6), y1, args(7), args(8), args(9))
                Case 3
                    delta0 += c5 * f5.Invoke(args(6), args(7), y0, args(8), args(9))
                    delta1 += c5 * f5.Invoke(args(6), args(7), y1, args(8), args(9))
                Case 4
                    delta0 += c5 * f5.Invoke(args(6), args(7), args(8), y0, args(9))
                    delta1 += c5 * f5.Invoke(args(6), args(7), args(8), y1, args(9))
                Case 5
                    delta0 += c5 * f5.Invoke(args(6), args(7), args(8), args(9), y0)
                    delta1 += c5 * f5.Invoke(args(6), args(7), args(8), args(9), y1)
            End Select
        End If
        temp = y1 - (delta1 * (y1 - y0) / (delta1 - delta0))
        y0 = Round(y1, 3)
        y1 = Round(temp, 3)
        i += 1
        If i >= max_iter Then
            Exit Do
        End If
    Loop
    Return y1
End Function
'************************************************************************************
'* SPILLWAY HYDRAULICS FUNCTIONS                                                    *
'************************************************************************************
Public Overloads Shared Function f_Co(ByVal P As Single, ByVal Ho As Single) As Single
    Dim x As Single = P / Ho
    If (x < 2.8) Then
        Return (-0.0201 * (x ^ 6) + 0.2148 * (x ^ 5) - 0.915 * (x ^ 4) + 1.982 * (x ^ 3) - 2.3081 * (x ^ 2) +
1.414 * (x) + 1.7719)
    Else
        Return 2.18
    End If
End Function
Public Overloads Shared Function f_Co(ByVal P_over_Ho As Single) As Single
    Dim x As Single = P_over_Ho
    If (x < 2.8) Then
        Return (-0.0201 * (x ^ 6) + 0.2148 * (x ^ 5) - 0.915 * (x ^ 4) + 1.982 * (x ^ 3) - 2.3081 * (x ^ 2) +
1.414 * (x) + 1.7719)
    Else
        Return 2.18
    End If
```

```
    End Function
    Public Overloads Shared Function f_CincCo(ByVal P_over_Ho As Single, ByVal alfa As Single) As
Single
        'alfa in degrees
        Dim x As Single = P_over_Ho
        If alfa = 0 Then
            Return 1
        ElseIf alfa = 18 Then
            Return (1.01 - 0.02 * x + 0.01 * (x ^ 2) - 0.004 * (x ^ 3))
        ElseIf alfa = 33 Then
            Return (1.04 - 0.06 * x + 0.04 * (x ^ 2) - 0.01 * (x ^ 3))
        ElseIf alfa = 45 Then
            Return (1.06 - 0.13 * x + 0.1 * (x ^ 2) - 0.03 * (x ^ 3))
            'should be revised; maybe it is not true to make interpolation or extrapolation
        ElseIf alfa > 0 And alfa < 18 Then
            Return (f_CincCo(x, 18) - (f_CincCo(x, 33) - f_CincCo(x, 18)) / (33 - 18) * (18 - alfa))
        ElseIf (alfa > 18 And alfa < 33) Then
            Return (f_CincCo(x, 18) + (f_CincCo(x, 33) - f_CincCo(x, 18)) / (33 - 18) * (alfa - 18))
        ElseIf alfa > 33 And alfa < 45 Then
            Return (f_CincCo(x, 33) + (f_CincCo(x, 45) - f_CincCo(x, 33)) / (45 - 33) * (alfa - 33))
        ElseIf alfa > 45 Then
            Return (f_CincCo(x, 45) + (f_CincCo(x, 45) - f_CincCo(x, 33)) / (45 - 33) * (alfa - 45))
        End If
    End Function
    Public Overloads Shared Function f_CincCo(ByVal P As Single, ByVal Ho As Single, ByVal alfa As
Single) As Single
        'alfa in degrees
        Dim x As Single = P / Ho
        If alfa = 0 Then
            Return 1
        ElseIf alfa = 18 Then
            Return (1.01 - 0.02 * x + 0.01 * (x ^ 2) - 0.004 * (x ^ 3))
        ElseIf alfa = 33 Then
            Return (1.04 - 0.06 * x + 0.04 * (x ^ 2) - 0.01 * (x ^ 3))
        ElseIf alfa = 45 Then
            Return (1.06 - 0.13 * x + 0.1 * (x ^ 2) - 0.03 * (x ^ 3))
            'should be revised; maybe it is not true to make interpolation or extrapolation
        ElseIf alfa > 0 And alfa < 18 Then
            Return (f_CincCo(x, 18) - (f_CincCo(x, 33) - f_CincCo(x, 18)) / (33 - 18) * (18 - alfa))
        ElseIf (alfa > 18 And alfa < 33) Then
            Return (f_CincCo(x, 18) + (f_CincCo(x, 33) - f_CincCo(x, 18)) / (33 - 18) * (alfa - 18))
        ElseIf alfa > 33 And alfa < 45 Then
            Return (f_CincCo(x, 33) + (f_CincCo(x, 45) - f_CincCo(x, 33)) / (45 - 33) * (alfa - 33))
        ElseIf alfa > 45 Then
            Return (f_CincCo(x, 45) + (f_CincCo(x, 45) - f_CincCo(x, 33)) / (45 - 33) * (alfa - 45))
        End If
    End Function
    Public Shared Function f_CmeCo(ByVal He As Single, ByVal Ho As Single) As Single
        Dim x As Single = He / Ho
        Return (0.03 * (x ^ 3) - 0.14 * (x ^ 2) + 0.32 * (x) + 0.79)
    End Function
    Public Shared Function f_CmaCo(ByVal hd As Single, ByVal d As Single, ByVal He As Single) As
Single
        Dim x As Single = (hd + d) / He
        If (x <= 1.7) Then
            Return (-30.015 * (x ^ 6) + 246.11 * (x ^ 5) - 836.08 * (x ^ 4) + 1506.7 * (x ^ 3) - 1520.1 * (x ^ 2) +
815.14 * (x) - 180.98)
        Else
            Return 1
        End If
    End Function
```

```
        Public Shared Function f_CmsCo(ByVal hd As Single, ByVal He As Single) As Single
            Dim x As Single = hd / He
            If (x < 0.7) Then
                Return (-161.95 * (x ^ 6) + 416.35 * (x ^ 5) - 426.22 * (x ^ 4) + 224.51 * (x ^ 3) - 66.258 * (x ^ 2) +
11.212 * (x) + 0.0242)
            Else
                Return 1.0
            End If
        End Function
        Public Shared Function f_Cgate(ByVal d As Single, ByVal H1 As Single) As Single
            Dim x As Single = d / H1
            Return (-13.168 * (x ^ 6) + 29.721 * (x ^ 5) - 25.295 * (x ^ 4) + 9.8034 * (x ^ 3) - 1.5358 * (x ^ 2) -
0.0995 * (x) + 0.7341)
        End Function
        Public Overloads Shared Function f_Kp(ByVal description As String) As Single
            If description = "square" Then
                Return 0.02
            ElseIf description = "rounded" Then
                Return 0.01
            Else
                Return 0
            End If
        End Function
        Public Overloads Shared Function f_Kp(ByVal type As Byte) As Single
            If type = 1 Then  'x=1; square
                Return 0.02
            ElseIf type = 2 Then 'x=2; rounded
                Return 0.01
            Else  'x=3; pointed
                Return 0
            End If
        End Function
        Public Overloads Shared Function f_Ka(ByVal description As String) As Single
            If description = "square" Then
                Return 0.2
            ElseIf description = "rounded" Then
                Return 0.1
            Else
                Return 0
            End If
        End Function
        Public Overloads Shared Function f_Ka(ByVal type As Byte) As Single
            If type = 1 Then
                Return 0.2
            ElseIf type = 2 Then
                Return 0.1
            Else
                Return 0
            End If
        End Function
        'better function, H is needed for check
        Public Overloads Shared Function f_Qsplw(ByVal Ct As Single, ByVal L As Single, ByVal Ho As
Single, ByVal H As Single) As Single
            'no gated (or gates are fully open) overflow type spillway;
            'for this type the total effects are considered .
            If (H >= 0 And L >= 0) Then
                Return Ct * L * Ho ^ (3 / 2)
            Else
                Return 0
            End If
        End Function
```

```
    'have some problem, Ho maybe greater but, H may be lower; therefore above func is better, because of
the fact that the H is the real criteria to be considered.
    Public Overloads Shared Function f_Qsplw(ByVal Ct As Single, ByVal L As Single, ByVal Ho As
Single) As Single
        'no gated (or gates are fully open) overflow type spillway;
        'for this type the total effects are considered .
        If (Ho >= 0 And L >= 0) Then
            Return Ct * L * Ho ^ (3 / 2)
        Else
            Return 0
        End If
    End Function
    Public Shared Function f_Qsplw_g(ByVal C As Single, ByVal H1 As Single, ByVal d As Single, ByVal
L As Single) As Single
        'gated overflow spillway; only gate constant C is considered,
        ' but gates are fully open, it is a non-gated overflow spillway
        Dim H2 As Single = H1 - d
        Return 2 / 3 * ((2 * g) ^ 0.5) * C * L * (H1 ^ 1.5 - H2 ^ 1.5)
    End Function
    Public Shared Function f_Qslcw(ByVal C As Single, ByVal A As Single, ByVal h As Single) As Single
        If (h >= 0 And A >= 0) Then
            Return (C * A * (2 * g * h) ^ 0.5)
        Else
            Return 0
        End If
    End Function
    'stilling basin type calculation
    Public Shared Function f_sbtype(ByVal y1 As Single, ByVal y2 As Single, ByVal y3 As Single, ByVal
Q As Single, ByVal B As Single) As stillingbasin
        Dim result As New stillingbasin()
        Dim u1 As Single
        Dim Fr1 As Single
        Dim H3, H4 As Single
        u1 = f_u(Q, y1, 0, B)
        Fr1 = f_Fr(Q, y1, 0, B)

        H3 = (y1 * (4 + Fr1)) / 6
        H4 = (y1 * (9 + Fr1)) / 9
        'these are common for all type
        result.y1 = y1
        result.y2 = y2
        result.y3 = y3
        result.u1 = u1
        result.Fr1 = Fr1
        result.B = B
        If (y2 = y3) Then
            result.type = "I"
            result.L = y1 * (-0.1521 * Fr1 ^ 2 + 11.487 * Fr1 - 12.107)
            result.n_baffle_piers = 0
            result.vol_baffle_piers = 0
            result.n_chute_blocks = 0
            result.vol_chute_blocks = 0
        ElseIf (y2 > y3) Then
            If (Round(Fr1, 1) >= 4.5 And Round(u1, 0) >= 15) Then
                result.type = "II"
                result.L = 4.3 * y2
                result.TW = 0.97 * y2
                result.delta_usbr = 0.2 * y2
                result.delta = f_Es(Q, y2, 0, B) - f_Es(Q, y3, 0, B)
                result.n_baffle_piers = 0
                result.vol_baffle_piers = 0
```

```
            result.n_chute_blocks = CInt(B / (2 * y1))
            result.vol_chute_blocks = result.n_chute_blocks * (y1 ^ 3) / 2
        ElseIf (Round(Fr1, 1) >= 4.5 And Round(u1, 0) < 15) Then
            result.type = "III"
            result.L = 2.7 * y2
            result.TW = 0.83 * y2
            result.delta_usbr = H4
            result.delta = f_Es(Q, y2, 0, B) - f_Es(Q, y3, 0, B)
            result.n_baffle_piers = CInt(B / (1.5 * H3))
            result.vol_baffle_piers = result.n_baffle_piers * (0.7 * H3 * 0.75 * H3)
            result.n_chute_blocks = CInt(B / (2 * y1))
            result.vol_chute_blocks = result.n_chute_blocks * (y1 ^ 3) / 2
        ElseIf (Round(Fr1, 1) >= 2.5 And Round(Fr1, 0) < 4.5) Then
            result.type = "IV"
            result.L = 6.1 * y2
            result.TW = y2
            result.delta_usbr = H4
            result.delta = f_Es(Q, y2, 0, B) - f_Es(Q, y3, 0, B)
            result.n_baffle_piers = 0
            result.vol_baffle_piers = 0
            result.n_chute_blocks = CInt(B / (3.5 * y1))
            result.vol_chute_blocks = result.n_chute_blocks * (4 * y1 ^ 3) / 2
        Else
            result.type = "NA"
            result.L = 0
            result.TW = 0
            result.delta_usbr = 0
            result.delta = 0
            result.n_baffle_piers = 0
            result.vol_baffle_piers = 0
            result.n_chute_blocks = 0
            result.vol_chute_blocks = 0
        End If
    ElseIf (y2 < y3) Then
        result.type = "V"
        result.L = 0
        result.TW = 0
        result.delta_usbr = 0
        result.delta = 0
        result.n_baffle_piers = 0
        result.vol_baffle_piers = 0
        result.n_chute_blocks = 0
        result.vol_chute_blocks = 0
    End If
    Return result
End Function
'seepage analysis (Lane's creep analysis) functions
Public Shared Function f_Lcreep(ByVal crpath() As c_point) As Single
    'crpath:creep_path
    Dim i As Integer
    Dim alfa As Single
    Dim Lcr As Single = 0 ' creep length
    For i = 0 To (crpath.GetUpperBound(0) - 1) 'last point is boundary (not a length)
        'alfa in degrees
        alfa = Abs(Atan((crpath(i + 1).y - crpath(i).y) / (crpath(i + 1).x - crpath(i).x)) * 360 / (2 * PI))
        If alfa >= 45 Then 'vertical
            Lcr = Lcr + Abs(crpath(i + 1).y - crpath(i).y)
        Else 'horizantal
            Lcr = Lcr + Abs(crpath(i + 1).x - crpath(i).x) / 3
        End If
    Next
```

```
            Return Lcr
        End Function
        'Darcy_Weissbach friction coeff. functions
        Public Shared Function f_f_roughp(ByVal Dp As Single, ByVal ks As Single) As Single
            Dim r As Single = Dp / 2
            Return (1 / (2 * Log10(r / ks) + 1.75)) ^ 2
        End Function
#Region "Polynomial calculations"
        Public Shared Function f_poly_A(ByVal points() As c_point) As Single
            'Assume that the last point is connected to the first point (there is need to define the first point as the
last point again)
            'this function may return area + or - acc to the direction used
            'area is + in ccw, - in cw directions.
            ' + or - value is needed for centroid calculations therefore another function taking the absolute was
defined
            Dim i As Integer
            Dim area As Single = 0
            For i = 0 To points.GetUpperBound(0) - 1
                area = area + (points(i).x * points(i + 1).y - points(i + 1).x * points(i).y)
            Next
            area = area / 2
            Return area
        End Function
        Public Shared Function f_poly_area(ByVal points() As c_point) As Single
            'this function returns the abs area of polygon
            Return Abs(f_poly_A(points))
        End Function
        Public Shared Function f_poly_centr(ByVal points() As c_point) As c_point
            'Asssume that the points of the polygon are arranged in clockwise
            'Assume that the last point is connected to the first point (no need to define the first point twice)
            Dim i As Integer
            Dim centr As New c_point(0, 0)
            Dim A As Single
            A = f_poly_A(points)
            For i = 0 To points.GetUpperBound(0) - 1
                centr.x = centr.x + (points(i).x + points(i + 1).x) * (points(i).x * points(i + 1).y - points(i + 1).x *
points(i).y)
                centr.y = centr.y + (points(i).y + points(i + 1).y) * (points(i).x * points(i + 1).y - points(i + 1).x *
points(i).y)
            Next

            centr.x = centr.x / (6 * A)
            centr.y = centr.y / (6 * A)
            Return centr
        End Function
#End Region
        Public Shared Function f_trap_centr_d_from_l(ByVal b As Single, ByVal a As Single) As Single
            'typical trapezoid cenroid with a smaller width whereas b greater width
            'l is the vertical length of trap
            Return (a ^ 2 + b ^ 2 + a * b) / (3 * (a + b))
        End Function
        Public Shared Function f_trap_centr_d_from_b(ByVal b As Single, ByVal a As Single, ByVal l As
Single) As Single
            'typical trapezoid cenroid with a smaller width whereas b greater width
            Return (l * (2 * a + b)) / (3 * (a + b))
        End Function
        'for computation messages
        Public Shared Function f_comp_inf(ByVal percent As Single, ByVal message As String, ByVal state As
Byte) As computation_information
            Dim result As New computation_information()
            result.percent = percent
```

```
            result.message = message
            result.state = state
            Return result
        End Function
    End Class
    <Serializable()> Public Class xsec_hyd
        '*************************************************************************************
        '* CLASS DECLERATION: X-SECTIONAL HYDRAULIC CALCULATIONS                             *
        '*************************************************************************************
        '* EXPLANATION: 3 types of problem can be solved                                     *
        '*          Each type is explained in "Construction Region" of the class.            *
        '*          Each constructor corresponds to 1 type of problem.                       *
        '*************************************************************************************
        '* GIVEN : acc.to the type of problem, it changes (look at "Constructor Region")     *
        '*************************************************************************************
        '* OUTPUT: All hydraulic characteristic of that cross-section.                       *
        '*************************************************************************************
        '* WRITTEN BY: KAMIL HAKAN TURAN                                                     *
        '* DATE:13.08.2003                                                                   *
        '*************************************************************************************
#Region "Private variables: (class core)"
        Private prb_type As Byte 'to indicate the type of problem
        Private y As Single 'normal depth as section)
        Private B As Single
        Private mh As Single
        Private n As Single
        Private A As Single
        Private P As Single
        Private T As Single
        Private Dy As Single
        Private R As Single
        Private Sf As Single
        Private Q As Single
        Private u As Single
        Private vel_head As Single
        Private Hgl As Single
        Private Egl As Single
        Private ycritical As Single
        Private Fr As Single
        Private flow As String
        Private Kb As Single  'bottom elevation of x-section(ground elevation)
        Private Sfc As Single
        Private Es As Single
        Private Esmin As Single
        Private km_xsec As Single  'horizantal cross section km (for functionality of other computations)
        Private tslab As Single  'slab thickness for concrete volume comp
        Private twall As Single  'wall thickness for concrete volume comp
#End Region
#Region "class interface"
        Private Sub compute()
            Select Case prb_type
                Case 1
                    Q = f_Qmann(B, mh, y, n, Sf)
                Case 2
                    y = f_ynormal(Q, B, mh, n, Sf)
                Case 3
                    Sf = f_Sf(Q, y, B, mh, n)
            End Select
            T = f_T(B, mh, y)
            A = f_A(B, mh, y)
            P = f_P(B, mh, y)
```

```
            R = A / P
            Dy = A / T
            u = f_u(Q, A)
            vel_head = f_velhead(u)
            Fr = f_Fr(u, Dy)
            flow = f_flow(Fr)
            ycritical = f_ycritical(Q, B, mh)
            Es = f_Es(Q, y, u)
            Esmin = f_Esmin(Q, B, mh)
            Hgl = f_HGL(Kb, y)
            Egl = f_EGL(Kb, u, y)
            Sfc = f_Sfc(Q, B, mh, n)
        End Sub
#End Region
#Region "Poperties section: "
        '"_p" hold for the word "Property"; read and write allowed
        '"_pro" hold for the word "Property"; Read Only....pro
        '"_pwo" hold for the word "Property"; Write Only...pwo
        Public Property tslab_p() As Single
            Set(ByVal Value As Single)
                tslab = Value
            End Set
            Get
                Return tslab
            End Get
        End Property
        Public Property twall_p() As Single
            Set(ByVal Value As Single)
                twall = Value
            End Set
            Get
                Return twall
            End Get
        End Property
        Public Property km_xsec_p() As Single
            Set(ByVal Value As Single)
                km_xsec = Value
            End Set
            Get
                Return km_xsec
            End Get
        End Property
        Public ReadOnly Property prb_type_pro() As Byte
            Get
                Return prb_type
            End Get
        End Property
        Public ReadOnly Property y_pro() As Single
            Get
                Return y
            End Get
        End Property
        Public ReadOnly Property B_pro() As Single
            Get
                Return B
            End Get
        End Property
        Public ReadOnly Property mh_pro() As Single
            Get
                Return mh
            End Get
```

```
End Property
Public ReadOnly Property n_pro() As Single
   Get
      Return n
   End Get
End Property
Public ReadOnly Property A_pro() As Single
   Get
      Return A
   End Get
End Property
Public ReadOnly Property P_pro() As Single
   Get
      Return P
   End Get
End Property
'not important for hydraulics, only to determine canal structure
'freeboard
Public ReadOnly Property f_pro() As Single
   Get
      Return 0.2 * (1 + y)
   End Get
End Property
'canal top elevation
Public ReadOnly Property Kt_pro() As Single
   Get
      Return (f_pro + y + Kb)
   End Get
End Property
'canal height
Public ReadOnly Property z_pro() As Single
   Get
      Return (Kt_pro - Kb_pro)
   End Get
End Property
Public ReadOnly Property T_pro() As Single
   Get
      Return T
   End Get
End Property
Public ReadOnly Property Dy_pro() As Single
   Get
      Return Dy
   End Get
End Property
Public ReadOnly Property R_pro() As Single
   Get
      Return R
   End Get
End Property
Public ReadOnly Property Sf_pro() As Single
   Get
      Return Sf
   End Get
End Property
Public ReadOnly Property Q_pro() As Single
   Get
      Return Q
   End Get
End Property
Public ReadOnly Property u_pro() As Single
```

```
    Get
      Return u
    End Get
End Property
Public ReadOnly Property vel_head_pro() As Single
    Get
      Return vel_head
    End Get
End Property
Public ReadOnly Property Hgl_pro() As Single
    Get
      Return Hgl
    End Get
End Property
Public ReadOnly Property Egl_pro() As Single
    Get
      Return Egl
    End Get
End Property
Public ReadOnly Property ycritical_pro() As Single
    Get
      Return ycritical
    End Get
End Property
'
Public ReadOnly Property Fr_pro() As Single
    Get
      Return Fr
    End Get
End Property
Public ReadOnly Property flow_pro() As String
    Get
      Return flow
    End Get
End Property
Public ReadOnly Property Kb_pro() As Single
    Get
      Return Kb
    End Get
End Property
Public ReadOnly Property Sfc_pro() As Single
    Get
      Return Sfc
    End Get
End Property
Public ReadOnly Property Es_pro() As Single
    Get
      Return Es
    End Get
End Property
Public ReadOnly Property Esmin_pro() As Single
    Get
      Return Esmin
    End Get
End Property
Public ReadOnly Property Aconc_sides_pro() As Single 'concrete area
    Get
      Return (Sqrt(1 + mh ^ 2) * z_pro * 2 * twall)
    End Get
End Property
Public ReadOnly Property Aconc_slab_pro() As Single 'concrete area
```

```
            Get
                Return B * tslab
            End Get
        End Property
        Public ReadOnly Property Aconc_tot_pro() As Single 'concrete area
            Get
                Return (Sqrt(1 + mh ^ 2) * z_pro * 2 * twall) + B * tslab
            End Get
        End Property
#End Region
#Region "Constructor section:"
        'copy constructor
        Public Sub New(ByVal inp As xsec_hyd)
            Me.A = inp.A
            Me.B = inp.B
            Me.Dy = inp.Dy
            Me.Egl = inp.Egl
            Me.Es = inp.Es
            Me.Esmin = inp.Esmin
            Me.flow = inp.flow
            Me.Fr = inp.Fr
            Me.Hgl = inp.Hgl
            Me.Kb = inp.Kb
            Me.km_xsec = inp.km_xsec
            Me.mh = inp.mh
            Me.n = inp.n
            Me.P = inp.P
            Me.prb_type = inp.prb_type
            Me.Q = inp.Q
            Me.R = inp.R
            Me.Sf = inp.Sf
            Me.Sfc = inp.Sfc
            Me.T = inp.T
            Me.tslab = inp.tslab
            Me.twall = inp.twall
            Me.u = inp.u
            Me.vel_head = inp.vel_head
            Me.y = inp.y
            Me.ycritical = inp.ycritical
        End Sub
        Public Sub New(ByVal water_depth As Double, ByVal horizantal_inclination As Double, ByVal
bottom_width As Double, ByVal manning_n As Double, ByVal friction_slope As Double, Optional ByVal
bottom_elevation As Double = 0.0, Optional ByVal xsection_km As Double = 0.0, Optional ByVal inp_tslab
As Double = 0, Optional ByVal inp_twall As Double = 0)
            '**********************************************************
            '* PROBLEM TYPE-1 : MANNING DISCHARGE CALCULATION  *
            '* GIVEN: xsection data,normal depth                *
            '* OUTPUT: Q: Manning discharge                     *
            '**********************************************************
            prb_type = 1
            y = water_depth
            mh = horizantal_inclination
            B = bottom_width
            n = manning_n
            Sf = friction_slope
            Kb = bottom_elevation
            km_xsec = xsection_km
            tslab = inp_tslab
            twall = inp_twall
            Me.compute()
        End Sub
```

```
    Public Sub New(ByVal discharge As Double, ByVal horizantal_inclination As Double, ByVal
bottom_width As Double, ByVal manning_n As Double, ByVal friction_slope As Double, ByVal description1
As Boolean, Optional ByVal bottom_elevation As Double = 0.0, Optional ByVal xsection_km As Double =
0.0, Optional ByVal inp_tslab As Double = 0, Optional ByVal inp_twall As Double = 0)
        ''*****************************************************
        '* PROBLEM TYPE-2 : NORMAL DEPTH CALCULATION      *
        '* GIVEN: x-section data, discharge                *
        '* OUTPUT: y: normal depth                         *
        '*****************************************************
        prb_type = 2
        Q = discharge
        mh = horizantal_inclination
        B = bottom_width
        n = manning_n
        Sf = friction_slope
        Kb = bottom_elevation
        km_xsec = xsection_km
        tslab = inp_tslab
        twall = inp_twall
        Me.compute()
    End Sub
    Public Sub New(ByVal discharge As Double, ByVal water_depth As Double, ByVal
horizantal_inclination As Double, ByVal bottom_width As Double, ByVal manning_n As Double, ByVal
description1 As Boolean, ByVal description2 As Boolean, Optional ByVal bottom_elevation As Double = 0.0,
Optional ByVal xsection_km As Double = 0.0, Optional ByVal inp_tslab As Double = 0, Optional ByVal
inp_twall As Double = 0)
        ''*****************************************************
        '* PROBLEM TYPE-3 :  FRICTION SLOPE CALCULATION   *
        '* GIVEN: x-section data, discharge,normal depth   *
        '* OUTPUT: Sf: friction slope                      *
        '*****************************************************
        prb_type = 3
        Q = discharge
        y = water_depth
        mh = horizantal_inclination
        B = bottom_width
        n = manning_n
        Kb = bottom_elevation
        km_xsec = xsection_km
        tslab = inp_tslab
        twall = inp_twall

        Me.compute()
    End Sub
#End Region
  End Class
  <Serializable()> Public Class ws_profile
    'this class is only for trapezoidal type prismatic channels (bed elev and xsec constant)
    'for the time being it is only for subcritical flows (mild slope); calculation; from d/s to u/s
    Public Shared max_iter_sstep As Integer = 500
    Public Shared max_iter_wsp_ynormal As Integer = 500
    Public Shared max_iter_wsp_Lx As Integer = 500
#Region "Private variables"
    'input and output
    Private xsec(0) As xsec_hyd  'initially 1 xsec, in need it will be increased dynamically (redim)
    Private err(0) As Single
    Private H2a As Single 'second xsec head (1st eqn)
    Private H2b As Single 'second xsec head (2nd eqn)
    Private dx As Single
    Private Lx As Single
    Private y_start As Single
```

```
    Private y_end As Single
    Private prb_type2 As Boolean
    Private Lx_end As Single
    Private y_end_comp As Single
    Private So As Single  'channel bed slope const, req to find the elev of new xsec
    Private Sf_ave As Single  'average friction slope btw sections
    'in order to use this function in other class it was declared as public
    Public Shared Function f_dy2(ByVal inp_err As Single, ByVal inp_dx As Single, ByVal inp_Fr2 As
Single, ByVal inp_Sf2 As Single, ByVal inp_R2 As Single) As Single
        Return (inp_err / (1 - inp_Fr2 ^ 2 + 3 * inp_Sf2 * inp_dx / (2 * inp_R2)))
    End Function
    Private Sub calculate_y2(ByVal i As Integer)
        Dim y_assumed As Single
        Dim dy2 As Single
        Dim iter As Integer = 0
        'a big assumed value,from d/s to u/s y2 will be greater than the preceding
        y_assumed = xsec(i).y_pro + 10
        err(i) = 1000 'initially big value
        Do Until (Abs(err(i)) <= 0.0001)
            xsec(i + 1) = New xsec_hyd(xsec(0).Q_pro, y_assumed, xsec(0).mh_pro, xsec(0).B_pro,
xsec(0).n_pro, True, True, xsec(i).Kb_pro + So * dx, xsec(i).km_xsec_p - dx)
            H2a = xsec(i + 1).Egl_pro
            Sf_ave = (xsec(i).Sf_pro + xsec(i + 1).Sf_pro) / 2
            H2b = xsec(i).Egl_pro + Sf_ave * dx
            err(i) = H2a - H2b
            dy2 = f_dy2(err(i), dx, xsec(i + 1).Fr_pro, xsec(i + 1).Sf_pro, xsec(i + 1).R_pro)
            y_assumed -= dy2
            iter += 1
            If iter >= max_iter_sstep Then
                Exit Do
            End If
        Loop
    End Sub
#End Region
#Region "Class interface"
    Private Sub compute()
        Dim i As Integer
        'check the input (the program works for subcritical regime )
        If (xsec(0).flow_pro <> "supercritical") Then
            If prb_type2 = False Then
                If (y_end > xsec(0).y_pro) Then
                    i = 0
                    Lx = 0
                    Do Until (Round(xsec(i).y_pro, 3) >= Round(y_end, 3))
                        ReDim Preserve xsec(xsec.GetUpperBound(0) + 1)
                        ReDim Preserve err(xsec.GetUpperBound(0))
                        calculate_y2(i)
                        Lx += dx
                        i += 1
                        If i >= max_iter_wsp_ynormal Then
                            Exit Do
                        End If
                    Loop
                    y_end_comp = xsec(i).y_pro
                Else
                    i = 0
                    Lx = 0
                    Do Until (Round(xsec(i).y_pro, 3) <= Round(y_end, 3))
                        ReDim Preserve xsec(xsec.GetUpperBound(0) + 1)
                        ReDim Preserve err(xsec.GetUpperBound(0))
                        calculate_y2(i)
```

```
                Lx += dx
                i += 1
                If i >= max_iter_wsp_ynormal Then
                    Exit Do
                End If
            Loop
            y_end_comp = xsec(i).y_pro
        End If
    Else
        Lx = 0
        Do Until (Lx >= Lx_end)
            ReDim Preserve xsec(xsec.GetUpperBound(0) + 1)
            ReDim Preserve err(xsec.GetUpperBound(0))
            calculate_y2(i)
            Lx += dx
            i += 1
            If i >= max_iter_wsp_Lx Then
                Exit Do
            End If
        Loop
        y_end_comp = xsec(i).y_pro
    End If
End If
End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property xsec_pro() As xsec_hyd()
        Get
            Return xsec
        End Get
    End Property
    Public ReadOnly Property err_pro() As Single()
        Get
            Return err
        End Get
    End Property
    Public ReadOnly Property y_end_comp_pro() As Single
        Get
            Return y_end_comp
        End Get
    End Property
    Public ReadOnly Property Lx_pro() As Single
        Get
            Return Lx
        End Get
    End Property
#End Region
#Region "Constructors"
    Public Sub New(ByVal inp_Q As Single, ByVal inp_n As Single, ByVal inp_B As Single, ByVal inp_So
As Single, ByVal inp_Kb As Single, ByVal inp_mh As Single, ByVal inp_y_start As Single, ByVal
inp_y_end As Single, ByVal inp_dx As Single)
        'computation is made for a boundary depth; therefore Lx(length when this depth occurs) calculated
        xsec(0) = New xsec_hyd(inp_Q, inp_y_start, inp_mh, inp_B, inp_n, True, True, inp_Kb, 0)
        y_start = inp_y_start
        y_end = inp_y_end
        So = inp_So
        dx = inp_dx
        prb_type2 = False
        Me.compute()
    End Sub
```

```
        Public Sub New(ByVal inp_Q As Single, ByVal inp_n As Single, ByVal inp_B As Single, ByVal inp_So
As Single, ByVal inp_Kb As Single, ByVal inp_mh As Single, ByVal inp_y_start As Single, ByVal
inp_Lx_end As Single, ByVal inp_dx As Single, ByVal inp_Lx_type As Boolean) 'prb_type is only for
making overloading
            'computation is made for a a determined length ; therefore y(wdepth) at that length loc is calculated.
            xsec(0) = New xsec_hyd(inp_Q, inp_y_start, inp_mh, inp_B, inp_n, True, True, inp_Kb, 0)
            y_start = inp_y_start
            So = inp_So
            dx = inp_dx
            Lx_end = inp_Lx_end
            prb_type2 = True
            Me.compute()
        End Sub
#End Region
    End Class
#End Region
End Namespace
Namespace intake_design
#Region "data structures"
    <Serializable()> Public Class intake_input_data
        Public Qi As Single             ': irrigation discharge
        Public Bop As Single            ': optimum bottom width of main irrigation canal
        Public So As Single             ': bottom slope of main irrigation canal
        Public mh As Single             ': vertical slope of side of trapezoidal canal (main irrigation canal)
        Public n As Single              ': Manning's roughness coeff.for lined canals (main irrigation canal and
intake structure)
        Public K0 As Single             ': bottom elevation at the beginning of the main irrigation canal
        Public B1 As Single             ': bottom width at section-1 (rect.intake canal) B1~2*Bop
        Public B1_inc As Single         ': increment value for B1
        Public t As Single              ': thickness of piers at section-2
        Public np As Integer            ': no of piers at section-2
        Public Bs As Single             ': channel width at section-3
        Public Bs_inc As Single         ': Bs increment value
        Public Sd As Single             ': Settling basin slope
        Public Dm As Single             ': min size of sediment to be settled in settling basin
        Public r As Single              ': sediment removal ratio
        Public np2 As Integer           ': no of piers at section-7 (entrance of the intake)
        Public t2 As Single             ': thickness of piers at section-7 (entrance of the intake)
        Public t_tr As Single           ': thickness of rackbars at the entrance of intake
        Public n_tr As Integer          ': number of rackbars
        Public Dfo As Single            ': max. diameter of floating objects to be allowed to enter the intake
        Public dsu As Single            ': upward sill height (at section-4)
        Public dsu_max As Single        ': max.allowable value for upward sill height (at section-4)
        Public dsu_inc As Single        ': increment value for calculating upward sill height (at section-4)
        Public Ls As Single             ': length of settling basin
        Public Ls_inc As Single         ': increment value for calculation of Ls
        Public dsd As Single            ': downward step height at section-6
        Public dsd_inc As Single        ': increment value for calculation of downward step height
        Public du_min As Single         ': min.allowable height for upward step (infront of intake)
        Public du_max As Single         ': max.allowable height for upward step (infront of intake)
        Public dHes As Single           ': minorloss above dsd (default=0.02)
        Public Cc As Single             ': headloss coeff through the curvature (default~0.2)
        Public Cyc As Single            ': coeff of critical depth at section-1 in order to calculate limitation
(default=1.1)
        Public Ct As Single             ': headloss coeff. through the transition btw section-0 and section-1
(default=0.3 for straight transition)
        Public K As Single              ': headloss coeff.through the gate (orifice constant) (at section-3 to section-4
and at entrance of intake)
        Public Kv As Single             ': the Von Korman constant for calculation of Ls (settling basin length)
        Public u4_max As Single         ': max allowable velocity for settlement of sediment at section-5
```

```
    Public delta_Kwi As Single       ': Kwi increment for calculating Ks in order to calculate crest elev. of
spillway
    Public Kst As Single            ': min.channel elev at the most u/s section (section where spillway is
constructed)
    Public hl_add As Single          ': any additional headloss value for calculation flexibility of different
problems
    'no need for hydraulic computations but needed for km_xsec
    Public L12 As Single            ': dist betw sect-1 and sect-2
    Public Lc As Single             ': length of curvature
    Public Lentr As Single          ': length at the entrance of intake (computed from creep lengths; no
additional input)
    Public Sub New(ByVal inp As intake_input_data)
      With Me
        .B1 = inp.B1
        .B1_inc = inp.B1_inc
        .Bop = inp.Bop
        .Bs = inp.Bs
        .Bs_inc = inp.Bs_inc
        .Cc = inp.Cc
        .Ct = inp.Ct
        .Cyc = inp.Cyc
        .delta_Kwi = inp.delta_Kwi
        .Dfo = inp.Dfo
        .dHes = inp.dHes
        .Dm = inp.Dm
        .dsd = inp.dsd
        .dsd_inc = inp.dsd_inc
        .dsu = inp.dsu
        .dsu_inc = inp.dsu_inc
        .dsu_max = inp.dsu_max
        .du_max = inp.du_max
        .du_min = inp.du_min
        .hl_add = inp.hl_add
        .K = inp.K
        .K0 = inp.K0
        .Kst = inp.Kst
        .Kv = inp.Kv
        .L12 = inp.L12
        .Lc = inp.Lc
        .Lentr = inp.Lentr
        .Ls = inp.Ls
        .Ls_inc = inp.Ls_inc
        .mh = inp.mh
        .n = inp.n
        .n_tr = inp.n_tr
        .np = inp.np
        .np2 = inp.np2
        .Qi = inp.Qi
        .r = inp.r
        .Sd = inp.Sd
        .So = inp.So
        .t = inp.t
        .t2 = inp.t2
        .t_tr = inp.t_tr
        .u4_max = inp.u4_max
      End With
    End Sub
    Public Sub New()
    End Sub
  End Class
#End Region
```

```
#Region "classes"
    <Serializable()> Public Class intake

'*******************************************************************************************
'** CLASS DECLERATION: TYPICAL INTAKE HYDRAULICS CALCULATIONS                              **
'*******************************************************************************************
'** EXPLANATION: A typical intake structure is hydraulicly computed. The class assumes      **
'**            that; the intake has typical sub-structures.Therefore the class does        **
'**            not have great flexibility for the computation of different intake          **
'**            structures. However, by given appropriate values (such as zero) some        **
'**            sections of the intake can be neglected.But you can not directly add        **
'**            sections to the typical sections. For this kind of flexible problems        **
'**            program structure should be expanded or some kind of computational          **
'**            games can be made in order to approach the output (spillway height)         **
'**            For the last section, an additional head loss variable is put inorder       **
'**            to take care of the additional sections.                                    **
'*******************************************************************************************
'** HOW TO USE THE CLASS: There are 2 constructors, one is for the use of the class         **
'**                 with some default values; therefore the default values are not         **
'**                 given as input data.                                                   **
'**                 The other one is more general constructor in which the default         **
'**                 values must also be given as input data.                               **
'**                 With initial data, the class is initialised and then with              **
'**                 "compute" method,the computation is made. For this part, every         **
'**                 limitation is considered and input data is changed with this           **
'**                 consideration. If you dont want the input values be changed by         **
'**                 program after the computation, assign to the suitable(write allowed)   **
'**                 properties the desired value.No need to use "compute" method again.    **
'**                 Because "compute" method is executed automatically with the            **
'**                 assignment procedure.                                                  **
'**                 Note that for the first time the program changes the values.           **
'*******************************************************************************************
'** GIVEN: All the necessary input data                                                     **
'*******************************************************************************************
'** OUTPUT: The spillway crest elevation and the other hydraulic properties of the intake sections.   **
'*******************************************************************************************
        Public Shared max_iter_B1 As Integer = 500
        Public Shared max_iter_dsu As Integer = 500 'for recursion
        Public Shared max_iter_Bs As Integer = 500 'for recursion
        Public Shared max_iter_dsd As Integer = 1000 'for recursion (for inrement 500 for decrement 500; total
1000)
#Region "Private variables"
        'inputs
        Private input_data As intake_input_data 'most used intake input data structure
        'outputs
        'readonly ones:
        Private Lt As Single            'length of transition
        Private Wf As Single
        Private ustar As Single
        Private us As Single
        Private ys As Single
        Private beta As Single
        Private lamda As Single
        Private An As Single
        Private Ag As Single
        Private un As Single
        Private Kwi As Single
        Private Ks As Single
        Private P As Single           'P is the spillway height from spillway thalweg elevation (imp: not from the
base of the spillway body)
        Private B2n As Single
```

```
Private dHi As Single
Private dHtr As Single
Private hl_section(8) As Single
Private xsec(8) As xsec_hyd

Private limits(8) As Boolean 'limitation variable if the required limitation for the section holds
Private du_i As Single   'initial du value
Private du As Single     'exact du value (including trashrack headloss)
Private Bsn As Single
Private compute_n_tr As Boolean
Private compute_Ls As Boolean
Private change_B1 As Boolean
Private change_Bs As Boolean
Private change_dsu As Boolean
Private change_dsd As Boolean
'recursion iteration variable
Private iter_dsu As Integer = 0
Private iter_Bs As Integer = 0
Private iter_dsd As Integer = 0
Private Sub section_0()
    With input_data
        xsec(0) = New xsec_hyd(.Qi, .mh, .Bop, .n, .So, True, .K0)
    End With
    With (xsec(0))
        If .y_pro >= 1.1 * .ycritical_pro Then
            limits(0) = True
        Else
            limits(0) = False
        End If
    End With
    hl_section(0) = 0
End Sub
Private Sub section_1()
    Dim i As Integer = 0
    Dim y1 As Single
    With input_data
        'hydraulic calculations
        y1 = f_y_hl_type1(.Qi, .B1, 0, .Ct, xsec(0).vel_head_pro, xsec(0).Es_pro)
        xsec(1) = New xsec_hyd(.Qi, y1, 0, .B1, .n, True, True, .K0)
        hl_section(1) = .Ct * (xsec(0).vel_head_pro - xsec(1).vel_head_pro)
        'limitations
        If xsec(0).u_pro > xsec(1).u_pro Then
            limits(1) = True
        ElseIf change_B1 Then
            'if limitation change is to be considered
            Do Until (xsec(0).u_pro > xsec(1).u_pro)
                .B1 += .B1_inc
                y1 = f_y_hl_type1(.Qi, .B1, 0, .Ct, xsec(0).vel_head_pro, xsec(0).Es_pro)
                xsec(1) = New xsec_hyd(.Qi, y1, 0, .B1, .n, True, True, .K0, )
                hl_section(1) = .Ct * (xsec(0).vel_head_pro - xsec(1).vel_head_pro)
                i += 1
                If i >= max_iter_B1 Then
                    Exit Do
                End If
            Loop
            If i < max_iter_B1 Then limits(1) = True
        Else
            limits(1) = False
        End If
        'length of transition
        Lt = 2.35 * (.B1 - .Bop) + 1.65 * .mh * xsec(1).y_pro
```

```
    End With
End Sub
Private Sub section_2()
    Dim u2, y2 As Single
    With input_data
        B2n = .B1 - .np * .t
        u2 = .Qi / (B2n * xsec(1).y_pro)
        'minor loss at the gate
        hl_section(2) = ((u2 / .K) ^ 2) / (2 * g)
        y2 = f_yalternate(xsec(1).Es_pro + hl_section(2), .Qi, B2n, 0)(0) 'subcritical depth; script(0)
        xsec(2) = New xsec_hyd(.Qi, y2, 0, B2n, .n, True, True, .K0)
        'no limitation but for program systematic
        limits(2) = True
    End With
End Sub
Private Sub section_3()
    Dim y3 As Single
    With input_data
        y3 = f_y_hl_type1(.Qi, .Bs, 0, .Cc, xsec(2).vel_head_pro, xsec(2).Es_pro)
        xsec(3) = New xsec_hyd(.Qi, y3, 0, .Bs, .n, True, True, .K0)
        hl_section(3) = .Cc * (xsec(2).vel_head_pro - xsec(3).vel_head_pro)
        'no limitation but for program systematic it was used
        limits(3) = True
    End With
End Sub
Private Sub section_4()
    Dim y4 As Single
    Dim i As Single
    With input_data
        hl_section(4) = f_delta_He(.Qi, .Bs, xsec(3).y_pro)
        y4 = f_yalternate(xsec(3).Es_pro + .dsu + hl_section(4), .Qi, .Bs, 0)(0) 'subcritical depth subscrip=0
        xsec(4) = New xsec_hyd(.Qi, y4, 0, .Bs, .n, True, True, xsec(3).Kb_pro - .dsu)
        'limitation
        If xsec(4).u_pro <= .u4_max Then
            limits(4) = True
        ElseIf ((change_dsu) And (.dsu <= .dsu_max)) Then
            .dsu += .dsu_inc
            y4 = f_yalternate(xsec(3).Es_pro + i + hl_section(4), .Qi, .Bs, 0)(0) 'subcritical depth subscript=0
            xsec(4) = New xsec_hyd(.Qi, y4, 0, .Bs, .n, True, True, xsec(3).Kb_pro - .dsu)
            section_3()
            section_4() 'recursive;
            iter_dsu += 1
            If iter_dsu >= max_iter_dsu Then
                Exit Sub
            End If
        ElseIf change_Bs Then
            .Bs += .Bs_inc
            y4 = f_yalternate(xsec(3).Es_pro + i + hl_section(4), .Qi, .Bs, 0)(0) 'subcritical depth subscript=0
            xsec(4) = New xsec_hyd(.Qi, y4, 0, .Bs, .n, True, True, xsec(3).Kb_pro - .dsu)
            section_3()
            section_4() 'recursive;
            iter_Bs += 1
            If iter_Bs >= max_iter_Bs Then
                Exit Sub
            End If
        Else
            limits(4) = False
        End If
    End With
End Sub
Private Sub section_5() 'settling basin
```

```
            With input_data
                Dim y5 As Single
                us = xsec(4).u_pro
                ys = xsec(4).y_pro
                ustar = f_ustar(ys, .Bs, 0, .Sd)
                Wf = f_Wf(.Dm)
                beta = f_beta(Wf, .Kv, ustar)
                lamda = f_lamda(beta)
                If compute_Ls Then
                    .Ls = f_Ls(.Kv, lamda, .r, ys, us, ustar)
                    .Ls += .Ls_inc
                End If
                y5 = f_implicite_root(f_Es(.Qi, xsec(4).y_pro, 0, xsec(4).B_pro) + .Ls / 2 * f_Sf(.Qi, xsec(4).n_pro,
xsec(4).A_pro, xsec(4).R_pro) - .Ls * .Sd, Nothing, Nothing, Nothing, AddressOf f_Es, AddressOf f_Sf, 0, 0,
0, -1, .Ls / 2, 0, 0, 2, 2, 0, 0, 0, .Qi, 0, .Bs, .Qi, .Bs, 0, .n)
                xsec(5) = New xsec_hyd(.Qi, y5, 0, .Bs, .n, True, True, xsec(4).Kb_pro + .Ls * .Sd)
                'head loss: Ls*(Sf5+Sf6)/2
                hl_section(5) = (f_Sf(.Qi, xsec(4).y_pro, xsec(4).B_pro, xsec(4).mh_pro, xsec(4).n_pro) + f_Sf(.Qi,
xsec(4).y_pro, xsec(4).B_pro, xsec(4).mh_pro, xsec(4).n_pro)) / 2 * .Ls
                'limitation (no limitation here, but for programming systematics
                limits(5) = True
            End With
        End Sub
        Private Sub section_6()
            Dim y6 As Single
            With input_data
                hl_section(6) = .dHes
                y6 = f_yalternate(f_Es(.Qi, xsec(5).y_pro, xsec(5).mh_pro, xsec(5).B_pro) + hl_section(6) - .dsd,
.Qi, .Bs, 0)(0)  'subcritical value needed,therefore subscript=0
                xsec(6) = New xsec_hyd(.Qi, y6, 0, .Bs, .n, True, True, xsec(5).Kb_pro + .dsd)
                'limitation (no limitation here, but for programming systematics
                limits(6) = True
            End With
        End Sub
        Private Sub section_7()
            Dim y7, u7, hl_orifice As Single
            With input_data
                Bsn = .Bs - .np2 * .t2
                u7 = .Qi / (Bsn * xsec(6).y_pro) 'approximate headloss
                'headloss at orifice, intake.
                hl_section(7) = ((u7 / .K) ^ 2) / (2 * g)
                y7 = f_yalternate(xsec(6).Es_pro + hl_section(7), .Qi, Bsn, 0)(0) 'subcritical depth
                xsec(7) = New xsec_hyd(.Qi, y7, 0, Bsn, .n, True, True, xsec(6).Kb_pro)
                'limitation (no limitation here, but for programming systematics
                limits(7) = True
            End With
        End Sub
        Private Sub section_8()
            Dim y8 As Single
            With input_data
                'headloss above the upward hill
                dHi = f_delta_He(.Qi, Bsn, xsec(7).y_pro)
                'headloss through the trashracks
                If compute_n_tr Then
                    .n_tr = CInt(Floor((Bsn / (.Dfo + .t_tr)) / 10) * 10) '????should be revised.
                End If
                An = (Bsn - .n_tr * .t_tr) * xsec(7).y_pro
                Ag = Bsn * xsec(7).y_pro
                un = .Qi / An
                dHtr = (1.45 - 0.45 * An / Ag - (An / Ag) ^ 2) * (un ^ 2) / (2 * g)
                'total headloss
```

```
            hl_section(8) = dHi + dHtr + .hl_add  'hl_add is added to last cross section to play with the crest elev
of spillway
            Kwi = xsec(6).Egl_pro + hl_section(7) + hl_section(8) - xsec(7).vel_head_pro
            Ks = Kwi + .delta_Kwi
            P = Ks - .Kst
            du_i = (Kwi - .Kst) - xsec(7).y_pro
            'limitation
            If (du_i >= .du_min And du_i <= .du_max) Then
               limits(8) = True
            ElseIf change_dsd Then
               If du_i < .du_min Then
                  .dsd += .dsd_inc
                  section_6()
                  section_7()
                  section_8() 'recursive :no loop needed, recursive is also a loop already
                  iter_dsd += 1
                  If iter_dsd >= max_iter_dsd Then
                     Exit Sub
                  End If
               ElseIf du_i > .du_max Then
                  .dsd -= .dsd_inc
                  section_6()
                  section_7()

                  section_8() 'recursive
                  iter_dsd += 1
                  If iter_dsd >= max_iter_dsd Then
                     Exit Sub
                  End If
               End If
            Else
               limits(8) = False
            End If
            'finally, the most u/s section at the intake is calculated (after u/s sill "du")
            du = (Kwi - .Kst) - hl_section(8) - xsec(7).y_pro '(remember calculation rule: from d/s to u/s)
            y8 = Kwi - .Kst
            'now no pier exist in xsex; so Bs was taken as bottom width
            xsec(8) = New xsec_hyd(.Qi, y8, 0, .Bs, .n, True, True, .Kst)
         End With
      End Sub
      'xsec km are determined
      Private Sub determine_xsec_km()
         Dim mh_delta = 2  'step hor. inclinations are taken as 2
         With input_data
            xsec(0).km_xsec_p = 0
            xsec(1).km_xsec_p = xsec(0).km_xsec_p - Lt
            xsec(2).km_xsec_p = xsec(1).km_xsec_p - .L12
            xsec(3).km_xsec_p = xsec(2).km_xsec_p - .Lc
            xsec(4).km_xsec_p = xsec(3).km_xsec_p - .dsu * mh_delta
            xsec(5).km_xsec_p = xsec(4).km_xsec_p - .Ls
            xsec(6).km_xsec_p = xsec(5).km_xsec_p - .dsd * mh_delta
            xsec(7).km_xsec_p = xsec(6).km_xsec_p - .Lentr
            xsec(8).km_xsec_p = xsec(7).km_xsec_p
         End With
      End Sub
#End Region
#Region "Properties Section"
#Region "read only properties"
      Public ReadOnly Property input_data_pro() As intake_input_data
         Get
            Return input_data
```

```
    End Get
End Property
Public ReadOnly Property tp_pro() As Single
    Get
        Return input_data.t
    End Get
End Property
Public ReadOnly Property tp2_pro() As Single
    Get
        Return input_data.t2
    End Get
End Property
Public ReadOnly Property np_pro() As Single
    Get
        Return input_data.np
    End Get
End Property
Public ReadOnly Property np2_pro() As Single
    Get
        Return input_data.np2
    End Get
End Property
Public ReadOnly Property Wf_pro() As Single
    Get
        Return Wf
    End Get
End Property
Public ReadOnly Property Lt_pro() As Single
    Get
        Return Lt
    End Get
End Property
Public ReadOnly Property ustar_pro() As Single
    Get
        Return ustar
    End Get
End Property
Public ReadOnly Property us_pro() As Single
    Get
        Return us
    End Get
End Property
Public ReadOnly Property lamda_pro() As Single
    Get
        Return lamda
    End Get
End Property
Public ReadOnly Property ys_pro() As Single
    Get
        Return ys
    End Get
End Property
Public ReadOnly Property du_i_pro() As Single
    Get
        Return du_i

    End Get
End Property
Public ReadOnly Property beta_pro() As Single
    Get
        Return beta
```

```
    End Get
End Property
Public ReadOnly Property un_pro() As Single
    Get
        Return un
    End Get
End Property
Public ReadOnly Property Ag_pro() As Single
    Get
        Return Ag
    End Get
End Property
Public ReadOnly Property An_pro() As Single
    Get
        Return An
    End Get
End Property
Public ReadOnly Property du_p() As Single
    Get
        Return du
    End Get
End Property
Public ReadOnly Property P_pro() As Single
    Get
        Return P
    End Get
End Property
Public ReadOnly Property B2n_pro() As Single
    Get
        Return B2n
    End Get
End Property
Public ReadOnly Property Ks_pro() As Single
    Get
        Return Ks
    End Get
End Property
Public ReadOnly Property Kwi_pro() As Single
    Get
        Return Kwi
    End Get
End Property
Public ReadOnly Property dHtr_pro() As Single
    Get
        Return dHtr
    End Get
End Property
Public ReadOnly Property dHi_pro() As Single
    Get
        Return dHi
    End Get
End Property
Public ReadOnly Property Bsn_pro() As Single
    Get
        Return Bsn
    End Get
End Property
Public ReadOnly Property hl_section_pro() As Single()
    Get
        Return hl_section
    End Get
```

```
    End Property
    Public ReadOnly Property xsec_pro() As xsec_hyd()
      Get
        Return xsec
      End Get
    End Property
    Public ReadOnly Property limits_pro() As Boolean()
      Get
        Return limits
      End Get
    End Property
#End Region
#Region "read and write allowed"
    Public Property dsd_p() As Single
      Get
        Return input_data.dsd
      End Get
      Set(ByVal Value As Single)
        change_dsd = False
        input_data.dsd = Value
        Me.compute()
      End Set
    End Property
    Public Property dsu_p() As Single
      Get
        Return input_data.dsu
      End Get
      Set(ByVal Value As Single)
        change_dsu = False
        input_data.dsu = Value
        Me.compute()
      End Set
    End Property
    Public Property n_tr_p() As Single
      Get
        Return input_data.n_tr
      End Get
      Set(ByVal Value As Single)
        compute_n_tr = False
        input_data.n_tr = Value
        Me.compute()
      End Set
    End Property
    Public Property Bs_p() As Single
      Get
        Return input_data.Bs
      End Get
      Set(ByVal Value As Single)
        change_Bs = False
        input_data.Bs = Value
        Me.compute()
      End Set
    End Property
    Public Property Ls_p() As Single
      Get
        Return input_data.Ls
      End Get
      Set(ByVal Value As Single)
        compute_Ls = False
        input_data.Ls = Value
        Me.compute()
```

```
        End Set
    End Property
    Public Property B1_p() As Single
        Get
            Return input_data.B1
        End Get
        Set(ByVal Value As Single)
            change_B1 = False
            input_data.B1 = Value
            Me.compute()
        End Set
    End Property
#End Region
#End Region
#Region "Class interface"
    Private Sub compute()
        section_0()
        section_1()
        section_2()
        section_3()
        section_4()
        section_5()
        section_6()
        section_7()
        section_8()
        determine_xsec_km()
    End Sub
#End Region
#Region "Constructors"
    Public Sub New(ByVal input As intake_input_data)
        input_data = input
        compute_n_tr = True
        compute_Ls = True
        change_B1 = True
        change_Bs = True
        change_dsu = True
        change_dsd = True
        Me.compute()
    End Sub
#End Region
  End Class
#End Region
End Namespace
Namespace splw_slcw_design
#Region "Data structures"
  <Serializable()> Public Class C_splw
    Public Co As Single
    Public Cinc As Single
    Public Cme As Single
    Public Cma As Single
    Public Cms As Single
    Public Com As Single  'this is the overall product of the constants Com=C0*Cinc*Cme*Cma*Cms
    Public Sub New(ByVal inp As C_splw) 'copy constr
        Me.Co = inp.Co
        Me.Cma = inp.Cma
        Me.Cinc = inp.Cinc
        Me.Cme = inp.Cme
        Me.Cms = inp.Cms
        Me.Com = inp.Com
    End Sub
    Public Sub New()
```

```
        End Sub
    End Class
    <Serializable()> Public Class splw_slcw_Q_input_data
        Public bridge_exist As Boolean
        Public Lt As Single
        Public np As Single  'if there is bridge over spillway; number of bridge piers
        Public tp As Single  'if there is bridge over spillway; thickness of each pier.
        Public Kp As Single  'piers contraction constant
        Public Ka As Single  'abutments contraction constant
        Public Le As Single
        Public nsl As Single
        Public d As Single
        Public tsl As Single
        Public Kst As Single          'thalweg(bottom) elevation at spillway section.(spillway thalweg elev)
        Public Ks As Single           'Spillway crest elevation...splway height; P=Ks-Kst
        Public Q() As Single          'total discharge values
        Public mh_s As Single          'u/s slope , horizantal component of slope; mv=1
        Public Kd() As Single          'downstream (tailwater) elevations for various discharges
        Public Kr As Single            'downstream (tailwater) river bottom (ground surface) elevations for various
discharges. interpolated section (riprap section)
        Public profile() As String  'profile name for discharges
        Public Sub New(ByVal inp As splw_slcw_Q_input_data)
            With Me
                .bridge_exist = inp.bridge_exist
                .d = inp.d
                .Ka = inp.Ka
                .Kd = inp.Kd.Clone()  'arrays should be cloned otherwise pointer equality occurs and this is
dangerous (not an exact copy occurs in that case)
                .Kp = inp.Kp
                .Kr = inp.Kr
                .Ks = inp.Ks
                .Kst = inp.Kst
                .Le = inp.Le
                .Lt = inp.Lt
                .mh_s = inp.mh_s
                .np = inp.np
                .nsl = inp.nsl
                .profile = inp.profile.Clone()
                .Q = inp.Q.Clone()
                .tp = inp.tp
                .tsl = inp.tsl
            End With
        End Sub
        Public Sub New()
        End Sub
    End Class
    <Serializable()> Public Class energy_dissp_input_data
        Public profile() As String  'profile name for discharges
        Public Q() As Single
        Public Qs() As Single
        Public Qsl() As Single
        Public K() As Single
        Public Kd() As Single
        Public Kr As Single
        Public Kst As Single
        Public nsl As Single
        Public tsl As Single
        Public Le As Single
        Public Lt As Single
        Public n_aprch As Single 'approach manning
        Public Sub New(ByVal inp As energy_dissp_input_data) 'copy constr
```

```
            With Me
                .K = inp.K.Clone()
                .Kd = inp.Kd.Clone()
                .Kr = inp.Kr
                .Kst = inp.Kst
                .Le = inp.Le
                .Lt = inp.Lt
                .n_aprch = inp.n_aprch
                .nsl = inp.nsl
                .profile = inp.profile.Clone()
                .Q = inp.Q.Clone()
                .Qs = inp.Qs.Clone()
                .Qsl = inp.Qsl.Clone()
                .tsl = inp.tsl
            End With
        End Sub
        Public Sub New()
        End Sub
    End Class
#End Region
#Region "Classes"
    <Serializable()> Public Class splw_slcw_Q
        'iteration limits
        Public Shared max_iter_K As Integer = 5000
#Region "private variables"
        'inputs
        Private input_data As splw_slcw_Q_input_data
        'outputs
        Private Ls As Single
        Private Ls_net As Single       'net crest length; length-pier thicknesses
        Private Ls_eff As Single       'effective crest lengh; net crest length - contraction effects
        Private Cs() As C_splw              'overflow spillway constants
        Private xsec_aprch() As xsec_hyd     'xsec infront of spillway and sluiceways; approach cross_section
        Private Qs() As Single
        Private Qsl() As Single
        Private Ho() As Single
        Private H() As Single
        Private K() As Single  'K100,K50,etc...
        Private Function f_diff_Q(ByVal i As Integer, ByVal Ki As Single) As Single
            With input_data
                Dim P As Single = .Ks - .Kst
                xsec_aprch(i) = New xsec_hyd(.Q(i), Ki - .Kst, 0, .Lt, 0.016, True, True, .Kst)
                Ho(i) = xsec_aprch(i).Egl_pro - .Ks
                H(i) = xsec_aprch(i).Hgl_pro - .Ks
                Ls_eff = Ls_net - 2 * (.np * .Kp + .Ka) * Ho(i)
                Cs(i) = New C_splw()
                'design head and varying head calculations
                If (i = 0) Then
                    Cs(i).Co = f_Co(P, Ho(i))

                Else
                    Cs(i).Co = Cs(0).Co
                End If
                Cs(i).Cinc = f_CincCo(P, Ho(i), Atan(.mh_s) / (2 * PI) * 360)
                Cs(i).Cme = f_CmeCo(Ho(i), Ho(0))    'Ho(0): design discharge
                Cs(i).Cma = f_CmaCo(xsec_aprch(i).Egl_pro - .Kd(i), .Kd(i) - .Kr, Ho(i))
                Cs(i).Cms = f_CmsCo(xsec_aprch(i).Egl_pro - .Kd(i), Ho(i))
                Cs(i).Com = Cs(i).Co * Cs(i).Cinc * Cs(i).Cme * Cs(i).Cma * Cs(i).Cms  'total of the effects
                Qs(i) = f_Qsplw(Cs(i).Com, Ls_eff, Ho(i), H(i))  'H(i) needed for check, overloaded function
                Qsl(i) = f_Qslcw(0.65, .nsl * .d * .Le, (Ki - .Kst))
                ' Debug.WriteLine("Cs(i).Cinc=" & Cs(i).Cinc)
```

```
            'Debug.WriteLine("Cs(i).Cma=" & Cs(i).Cma)
            'Debug.WriteLine("Cs(i).Cme=" & Cs(i).Cme)
            'Debug.WriteLine("Cs(i).Cms=" & Cs(i).Cms)
            ''Debug.WriteLine("Cs(i).Com=" & Cs(i).Com)
            Return (.Q(i) - (Qs(i) + Qsl(i)))
        End With
    End Function
#End Region
#Region "Properties"
    Public ReadOnly Property input_data_pro() As splw_slcw_Q_input_data
        Get
            Return Me.input_data
        End Get
    End Property
    Public ReadOnly Property Qsl_pro() As Single()
        Get
            Return Qsl
        End Get
    End Property
    Public ReadOnly Property Qs_pro() As Single()
        Get
            Return Qs
        End Get
    End Property
    Public ReadOnly Property Cs_pro() As C_splw()
        Get
            Return Cs
        End Get
    End Property
    Public ReadOnly Property Ho_pro() As Single()
        Get
            Return Ho
        End Get
    End Property
    Public ReadOnly Property K_pro() As Single()
        Get
            Return K
        End Get
    End Property
    Public ReadOnly Property xsec_aprch_pro() As xsec_hyd()
        Get
            Return xsec_aprch
        End Get
    End Property
    'sluiceway gate top el; just like spillw crest determ 10 cm freeboard added
    'in fact xsec_approach tan da bulunabilir
    Public ReadOnly Property Ksl_pro() As Single
        Get
            Return K(0) + 0.1
        End Get
    End Property
    Public ReadOnly Property Le_pro() As Single
        Get
            Return Me.input_data.Le
        End Get
    End Property
    Public ReadOnly Property Lt_pro() As Single
        Get
            Return Me.input_data.Lt
        End Get
    End Property
```

```
    Public ReadOnly Property Ls_pro() As Single
      Get
        Return Ls
      End Get
    End Property
    Public ReadOnly Property tsl_pro() As Single
      Get
        Return Me.input_data.tsl
      End Get
    End Property
    Public ReadOnly Property tp_pro() As Single
      Get
        Return Me.input_data.tp
      End Get
    End Property
    Public ReadOnly Property nsl_pro() As Single
      Get
        Return Me.input_data.nsl
      End Get
    End Property
    Public ReadOnly Property np_pro() As Single
      Get
        Return Me.input_data.np
      End Get
    End Property
    Public ReadOnly Property Ls_net_pro() As Single
      Get
        Return Ls_net
      End Get
    End Property
    Public ReadOnly Property Ls_eff_pro() As Single
      Get
        Return Ls_eff
      End Get
    End Property
    'Note: L=Ls+Lsl+tsl   (tsl: guide wall thickness)
    Public ReadOnly Property Lsl_pro() As Single
      Get
        With Me.input_data
          Return .nsl * .Le + (.nsl - 1) * .tsl
        End With
      End Get
    End Property
#End Region
#Region "Class interface"
    Private Sub compute()
      With input_data
        'initialize_data
        ' note Q(0) is always design discharge
        Dim i As Integer
        Dim iter As Integer = 0
        Dim Ki_a, Ki_b, Ki_c, Ki_c0 As Single
        Dim dx As Single
        Dim f_Ki_c As Single
        ' Dim delta As Single = 0.5
        Dim epsilon As Single = 0.1
        Ls = .Lt - .nsl * .tsl - .nsl * .Le
        Ls_net = Ls - .np * .tp  'net crest length
        For i = 0 To .Q.GetUpperBound(0)
          'regula Falsi method
          Ki_a = .Kst  'a 'assumed start value for K(i)
```

```
                'find the second bondary
                Ki_b = .Kst
                While (f_diff_Q(i, Ki_b) > 0)
                    Ki_b += 10  'b
                End While
                iter = 0 'reset the iteration num
                Do
                    If (iter >= max_iter_K) Then
                        Exit Do
                    End If
                    Ki_c = (Ki_a + Ki_b) / 2
                    f_Ki_c = f_diff_Q(i, Ki_c)
                    If (f_Ki_c = 0) Then
                        Exit Do
                    ElseIf (Sign(f_diff_Q(i, Ki_b)) = Sign(f_diff_Q(i, Ki_c))) Then
                        Ki_b = Ki_c
                    Else
                        Ki_a = Ki_c
                    End If
                    iter += 1
                    ' Debug.WriteLine(Ki_c)
                    ' Debug.WriteLine(f_diff_Q(i, Ki_c))
                Loop Until (Abs(f_diff_Q(i, Ki_c)) <= epsilon)  'if it comes to below the ground elev stop
                K(i) = Ki_c
                'Debug.WriteLine("-----------------------")
            Next
        End With
    End Sub
#End Region
#Region "Constructors"
    Public Sub New(ByVal input As splw_slcw_Q_input_data)
        input_data = input
        'for output arrays
        With input
            ReDim Cs(.Q.GetUpperBound(0))
            ReDim xsec_aprch(.Q.GetUpperBound(0))
            ReDim Qs(.Q.GetUpperBound(0))
            ReDim Qsl(.Q.GetUpperBound(0))
            ReDim Ho(.Q.GetUpperBound(0))
            ReDim H(.Q.GetUpperBound(0))
            ReDim K(.Q.GetUpperBound(0))
        End With
        Me.compute()
    End Sub
#End Region
  End Class
  <Serializable()> Public Class energy_dissp
#Region "Private variables"
    'input data
    Private input_data As energy_dissp_input_data
    'output data
    Private xsecus() As xsec_hyd
    Private xsecds_sl() As xsec_hyd
    Private xsecds_s() As xsec_hyd
    Private hl_s() As Single
    Private hl_sl() As Single
    Private stillbas_s() As stillingbasin
    Private stillbas_sl() As stillingbasin
    Private sb_common As Boolean 'common or sepearate stillbasin: 0 for seperate 1 for common
    Private resultsb_s As stillingbasin  'result, final choices
    Private resultsb_sl As stillingbasin
```

```
    'select sthe appropriate stilling basin from various alternatives
    Private Sub select_resultsb(ByVal sb_s() As stillingbasin, ByVal sb_sl() As stillingbasin)
        Dim i As Integer
        Dim pos As Integer 'position for the required index
        Dim L As Single = 0
        Dim delta As Single = 0
        'sort the stillbasin arrays acc to their lengths
        'spillway
        For i = 0 To sb_s.GetUpperBound(0)
            'finds max length and the other information
            If sb_s(i).L >= L Then
                L = sb_s(i).L
                pos = i
            End If
            'finds the max delta
            If sb_s(i).delta >= delta Then
                delta = sb_s(i).delta
            End If
        Next
        resultsb_s = New stillingbasin(sb_s(pos)) 'copy constr
        resultsb_s.delta = delta
        'sluiceway
        'initialize the sorting
        L = 0
        delta = 0
        For i = 0 To sb_sl.GetUpperBound(0)
            'finds max length and the other information
            If sb_sl(i).L >= L Then
                L = sb_sl(i).L
                pos = i
            End If
            'finds the max delta
            If sb_sl(i).delta >= delta Then
                delta = sb_sl(i).delta
            End If
        Next
        resultsb_sl = New stillingbasin(sb_sl(pos)) 'copy_constr
        resultsb_sl.delta = delta
        'decide if common or seperate stilling basin
        If Abs(resultsb_s.delta - resultsb_sl.delta) <= 0.5 Then
            sb_common = True
            'choose greater of delta to both
            resultsb_s.delta = Max(resultsb_s.delta, resultsb_sl.delta)
            resultsb_sl.delta = resultsb_s.delta
            'common stilling basin (the one with greater length)
            If Max(resultsb_s.L, resultsb_sl.L) = resultsb_s.L Then
                resultsb_sl = resultsb_s
            Else
                resultsb_s = resultsb_sl
            End If
        Else
            sb_common = False
            'common length but different stilling basins
            resultsb_s.L = Max(resultsb_s.L, resultsb_sl.L)
            resultsb_sl.L = resultsb_s.L
        End If
    End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property y2max_s_pro() As Single 'required for sidewall height
        Get
```

```
        Dim i As Integer
        Dim y2max_s As Single = 0
        For i = 0 To stillbas_s.GetUpperBound(0)
            If y2max_s < stillbas_s(i).y2 Then y2max_s = stillbas_s(i).y2
        Next
        Return y2max_s
    End Get
End Property
Public ReadOnly Property y2max_sl_pro() As Single 'required for sidewall height
    Get
        Dim i As Integer
        Dim y2max_sl As Single = 0
        For i = 0 To stillbas_sl.GetUpperBound(0)
            If y2max_sl < stillbas_sl(i).y2 Then y2max_sl = stillbas_sl(i).y2
        Next
        Return y2max_sl
    End Get
End Property
Public ReadOnly Property input_data_pro() As energy_dissp_input_data
    Get
        Return Me.input_data
    End Get
End Property
Public ReadOnly Property xsecus_pro() As xsec_hyd()
    Get
        Return xsecus
    End Get
End Property
Public ReadOnly Property xsecds_s_pro() As xsec_hyd()
    Get
        Return xsecds_s
    End Get
End Property
Public ReadOnly Property xsecds_sl_pro() As xsec_hyd()
    Get
        Return xsecds_sl
    End Get
End Property
Public ReadOnly Property hl_s_pro() As Single()
    Get
        Return hl_s
    End Get
End Property
Public ReadOnly Property hl_sl_pro() As Single()
    Get
        Return hl_sl
    End Get
End Property
Public ReadOnly Property stillbas_s_pro() As stillingbasin()
    Get
        Return stillbas_s
    End Get
End Property
Public ReadOnly Property stillbas_sl_pro() As stillingbasin()
    Get
        Return stillbas_sl
    End Get
End Property
Public ReadOnly Property resultsb_s_pro() As stillingbasin
    Get
        Return resultsb_s
```

```
            End Get
        End Property
        Public ReadOnly Property resultsb_sl_pro() As stillingbasin
            Get
                Return resultsb_sl
            End Get
        End Property
        Public ReadOnly Property sb_common_pro() As Boolean
            Get
                Return sb_common
            End Get
        End Property
        Public ReadOnly Property Lsb_pro() As Single
            Get
                Return resultsb_s.L
            End Get
        End Property
        Public ReadOnly Property type_s_pro() As Byte
            Get
                Return resultsb_s.type
            End Get
        End Property
        Public ReadOnly Property type_sl_pro() As Byte
            Get
                Return resultsb_sl.type
            End Get
        End Property
        Public ReadOnly Property delta_s_pro() As Single
            Get
                Return resultsb_s.delta
            End Get
        End Property
        Public ReadOnly Property delta_sl_pro() As Single
            Get
                Return resultsb_sl.delta
            End Get
        End Property
#End Region
#Region "class interface"

        Private Sub compute()
            Dim i As Integer
            Dim yconjugates_s(1) As Single ' for y1 and y2 for spillway
            Dim yconjugates_sl(1) As Single ' for y1 and y2 for sluiceway
            Dim L As Single
            With input_data
                L = .Lt - .nsl * .tsl - .nsl * .Le
                For i = 0 To .Q.GetUpperBound(0)
                    'u/s energy grade level
                    xsecus(i) = New xsec_hyd(.Q(i), .K(i) - .Kst, 0, .Lt, .n_aprch, True, True, .Kst)
                    'd/s energy grade level at spillway and sluiceway after hyd jump (not tw)
                    xsecds_s(i) = New xsec_hyd(.Qs(i), .Kd(i) - .Kr, 0, L, .n_aprch, True, True, .Kr)
                    xsecds_sl(i) = New xsec_hyd(.Qsl(i), .Kd(i) - .Kr, 0, (.nsl * .Le + (.nsl - 1) * .tsl), .n_aprch, True,
True, .Kr)
                    'head losses between u/s and d/s for spillway and sluiceway (head loss through hyd jump)
                    ' assume no head loss occurs at spillway face and sluiceway entrance
                    hl_s(i) = xsecus(i).Egl_pro - xsecds_s(i).Egl_pro
                    hl_sl(i) = xsecus(i).Egl_pro - xsecds_sl(i).Egl_pro
                    yconjugates_s = f_yconjugatehl(hl_s(i), xsecds_s(i).B_pro, xsecds_s(i).mh_pro,
xsecds_s(i).Q_pro)
```

```
                yconjugates_sl = f_yconjugatehl(hl_sl(i), xsecds_sl(i).B_pro, xsecds_sl(i).mh_pro,
xsecds_sl(i).Q_pro)
                stillbas_s(i) = f_sbtype(yconjugates_s(0), yconjugates_s(1), xsecds_s(i).y_pro, xsecds_s(i).Q_pro,
xsecds_s(i).B_pro)
                stillbas_sl(i) = f_sbtype(yconjugates_sl(0), yconjugates_sl(1), xsecds_sl(i).y_pro,
xsecds_sl(i).Q_pro, xsecds_sl(i).B_pro)
            Next
        End With
        'select the design final sb from the alternatives
        select_resultsb(stillbas_s, stillbas_sl)
    End Sub
#End Region
#Region "Constructors"
    Public Sub New(ByVal input As energy_dissp_input_data)
        input_data = input
        With input
            ReDim xsecus(.K.GetUpperBound(0))
            ReDim xsecds_sl(.K.GetUpperBound(0))
            ReDim xsecds_s(.K.GetUpperBound(0))
            ReDim hl_s(.K.GetUpperBound(0))
            ReDim hl_sl(.K.GetUpperBound(0))
            ReDim stillbas_s(.K.GetUpperBound(0))
            ReDim stillbas_sl(.K.GetUpperBound(0))
        End With
        Me.compute()
    End Sub
#End Region
  End Class
  <Serializable()> Public Class splw_profile
    'to be filled...
  End Class
#End Region
End Namespace
Namespace Appurtenant_fac
#Region "Classes"
  <Serializable()> Public Class riprap_des
#Region "Private variables"
    'inputs
    Private y3 As Single 'tailwater depth under Qdesign (for ex=Kd100)
    Private Lt As Single 'width of the river section
    Private Qdes As Single 'design discharge (max disch; for ex=Q100)
    Private So As Single  'mean river bed slope
    Private min_riprap_height As Single  ' min total riprap height
    Private Ld_min As Single 'minimum riprap length
    'outputs
    Private D As Single  'min diameter of riprap
    Private R As Single  'hydraulic radius
    Private Ld_comp As Single 'comp length of riprap
    Private Ld As Single 'decided Ld
    Private nrow As Single 'number of riprap row
    Private Vriprap As Single  'volume of riprap section
#End Region
#Region "Class interface"
    Private Sub compute()
        Dim q As Single
        q = Qdes / Lt
        R = y3 * Lt / (Lt + 2 * y3)
        D = 20 * R * So
        Ld_comp = 3 * q ^ (2 / 3) - 1.5 * y3
        If Ld_comp < Ld_min Then
            Ld = Ld_min
```

```
            Else
                Ld = Ld_comp
            End If
            nrow = Ceiling(min_riprap_height / D)
            Vriprap = Ld * nrow * D * Lt
        End Sub
#End Region
#Region "Properties"
        ReadOnly Property inp_Ld_min_pro() As Single
            Get
                Return Ld_min
            End Get
        End Property
        ReadOnly Property inp_min_riprap_height_pro() As Single
            Get
                Return min_riprap_height
            End Get
        End Property
        ReadOnly Property inp_So_pro() As Single
            Get
                Return So
            End Get
        End Property
        ReadOnly Property inp_y3_pro() As Single
            Get
                Return y3
            End Get
        End Property
        ReadOnly Property inp_Lt_pro() As Single
            Get
                Return Lt
            End Get
        End Property
        ReadOnly Property inp_Qdes_pro() As Single
            Get
                Return Qdes
            End Get
        End Property
        ReadOnly Property D_pro() As Single
            Get
                Return D
            End Get
        End Property
        ReadOnly Property Ld_pro() As Single
            Get
                Return Ld
            End Get
        End Property
        ReadOnly Property Ld_comp_pro() As Single
            Get
                Return Ld_comp
            End Get
        End Property
        ReadOnly Property R_pro() As Single
            Get
                Return R
            End Get
        End Property
        ReadOnly Property nrow_pro() As Single
            Get
                Return nrow
```

```
        End Get
      End Property
      ReadOnly Property Vriprap_pro() As Single
        Get
          Return Vriprap
        End Get
      End Property
#End Region
#Region "Constructors"
      Public Sub New(ByVal inp_y3 As Single, ByVal inp_Lt As Single, ByVal inp_Qdes As Single, ByVal
inp_So As Single, ByVal inp_min_riprap_height As Single, ByVal inp_Ld_min As Single)
        y3 = inp_y3
        Lt = inp_Lt
        Qdes = inp_Qdes
        So = inp_So
        min_riprap_height = inp_min_riprap_height
        Ld_min = inp_Ld_min
        Me.compute()
      End Sub
#End Region
    End Class
    <Serializable()> Public Class flushing_canal
      'iteration limits
      Public Shared max_iter_Dp As Integer = 100
#Region "Private variables"
      'inputs
      'assume fully-rough pipe (f=f(ks/D); for fully rough pipe) for hydraulic comp. of pipe
      Private Dm As Single 'max possible size of material to be settled
      Private Dp As Single  ' diameter of the flushing pipe
      Private n As Single  'manning roughness coeff for the pipe
      Private ks As Single   ' rougness coeff.
      Private delta As Single '(=1.65) relative density of the uniform sediment
      Private Lstill As Single  'horizantal length from the stilling basin
      Private Elstill As Single  'elevation at end of stilling basin
      Private Lsettl As Single  'horizantal length from the settling basin
      Private Elsettl As Single  'elevation at the end of settling basin
      Private incDp As Single ' pipe diameter tril increment
      'outputs
      Private ustarc As Single
      Private Tsoc As Single  ' critical shear stress
      Private Tso As Single   ' shear stress
      Private Lflush_h As Single ' horizantal length of flushing canal
      Private Sf As Single  ' friction loss through pipe
      Private So As Single   'required pipe(flushing canal) bed slope
      Private f As Single  ' darcy-weisbach friction factor
      Private u As Single 'velocity in pipe to satisfy the flushing of the settlement
      Private fi As Single 'for initial pipe diam
      Private ui As Single 'for initial pipe diam
      Private Sfi As Single  'min bed slope for initial pipe data(initial Sf)
#End Region
#Region "Class interface"
      Private Sub compute()
        Dim i As Integer = 0
        Lflush_h = Sqrt(Lsettl ^ 2 - Lstill ^ 2)
        So = Abs(Elsettl - Elstill) / Lflush_h
        Sf = 1000000 'initially a big value for first computation
        ustarc = f_ustarc(delta, Dm)
        Tsoc = pwater * ustarc ^ 2
        'for initial pipe diameter calculations
        fi = f_f_roughp(Dp, ks)
        ui = (Tsoc * 8 / (fi * pwater)) ^ 0.5
```

```
            Sfi = (n ^ 2) * (ui ^ 2) / ((Dp / 4) ^ (4 / 3))
            Sf = Sfi
            While (So <= Sf And i <= max_iter_Dp)
                f = f_f_roughp(Dp, ks)
                u = (Tsoc * 8 / (f * pwater)) ^ 0.5
                Tso = f / 8 * pwater * u ^ 2
                Sf = (n ^ 2) * (u ^ 2) / ((Dp / 4) ^ (4 / 3))
                Dp += incDp
                i += 1
            End While
        End Sub
#End Region
#Region "Properties"
        Public ReadOnly Property inp_Dm_pro() As Single
            Get
                Return Dm
            End Get
        End Property
        Public ReadOnly Property inp_n_pro() As Single
            Get
                Return n
            End Get
        End Property
        Public ReadOnly Property inp_ks_pro() As Single
            Get
                Return ks
            End Get
        End Property
        Public ReadOnly Property inp_delta_pro() As Single
            Get
                Return delta
            End Get
        End Property
        Public ReadOnly Property inp_Lstill_pro() As Single
            Get
                Return Lstill
            End Get
        End Property
        Public ReadOnly Property inp_ELstill_pro() As Single
            Get
                Return Elstill
            End Get
        End Property
        Public ReadOnly Property inp_Lsettl_pro() As Single
            Get
                Return Lsettl
            End Get
        End Property
        Public ReadOnly Property inp_incDp_pro() As Single
            Get
                Return incDp
            End Get
        End Property
        Public ReadOnly Property inp_Elsettl_pro() As Single
            Get
                Return Elsettl
            End Get
        End Property
        Public ReadOnly Property ustarc_pro() As Single
            Get
                Return ustarc
```

```
    End Get
End Property
Public ReadOnly Property Tsoc_pro() As Single
    Get
        Return Tsoc
    End Get
End Property
Public ReadOnly Property Tso_pro() As Single
    Get
        Return Tso
    End Get
End Property
'horizantal length of flushing canal
Public ReadOnly Property Lflush_h_pro() As Single
    Get

        Return Lflush_h
    End Get
End Property
'real (3d) length of flushing canal (need for cost calculations)
Public ReadOnly Property Lflush_pro() As Single
    Get
        Return Sqrt(Lflush_h ^ 2 + (Elsettl - Elstill) ^ 2)
    End Get
End Property
Public ReadOnly Property Sf_pro() As Single
    Get
        Return Sf
    End Get
End Property
Public ReadOnly Property So_pro() As Single
    Get
        Return So
    End Get
End Property
Public ReadOnly Property f_pro() As Single
    Get
        Return f
    End Get
End Property
Public ReadOnly Property u_pro() As Single
    Get
        Return u
    End Get
End Property
Public ReadOnly Property Dp_pro() As Single
    Get
        Return Dp
    End Get
End Property
Public ReadOnly Property Sfi_pro() As Single
    Get
        Return Sfi
    End Get
End Property
Public ReadOnly Property fi_pro() As Single
    Get
        Return fi
    End Get
End Property
Public ReadOnly Property ui_pro() As Single
```

```
            Get
                Return ui
            End Get
        End Property
#End Region
#Region "Constructors"
        Public Sub New(ByVal inp_Dm As Single, ByVal inp_Dp As Single, ByVal inp_n As Single, ByVal
inp_ks As Single, ByVal inp_delta As Single, ByVal inp_Lstill As Single, ByVal inp_Elstill As Single, ByVal
inp_Lsettl As Single, ByVal inp_Elsettl As Single, ByVal inp_incDp As Single)
            Dm = inp_Dm
            Dp = inp_Dp
            n = inp_n
            ks = inp_ks
            delta = inp_delta
            Lstill = inp_Lstill
            Elstill = inp_Elstill
            Lsettl = inp_Lsettl
            Elsettl = inp_Elsettl
            incDp = inp_incDp
            Me.compute()
        End Sub
        Public Sub New(ByVal inp_Dm As Single, ByVal inp_Dp As Single, ByVal inp_n As Single, ByVal
inp_ks As Single, ByVal inp_delta As Single, ByVal inp_Lsettl As Single, ByVal inp_Elsettl As Single,
ByVal inp_incDp As Single, ByVal inp_alfa_int As Single, ByVal inp_Kr As Single, ByVal inp_delta_sb As
Single, ByVal inp_So_river As Single, ByVal inp_Lstill_tot As Single)
            Dm = inp_Dm
            Dp = inp_Dp
            n = inp_n
            ks = inp_ks
            delta = inp_delta
            Lsettl = inp_Lsettl
            Elsettl = inp_Elsettl
            incDp = inp_incDp
            Lstill = Lsettl * Cos(inp_alfa_int * 2 * PI / 360)
            If Lstill < inp_Lstill_tot Then
                Elstill = inp_Kr - inp_delta_sb
            Else
                Elstill = inp_Kr - inp_So_river * (Lstill - inp_Lstill_tot)
            End If
            Me.compute()
        End Sub
#End Region
    End Class
#End Region
End Namespace
Namespace stability_analysis
#Region "Data structures"
    <Serializable()> Public Class MVo 'overturning moment base stress calc
        Public EMo As Single
        Public EMr As Single
        Public B_base As Single
        Public c_base As Single
        Public I_base As Single
        Public A_base As Single
        Public M_base As Single
        Public x_base As Single
        Public e_base As Single
        Public EV_base As Single
        Public Vtoe As Single
        Public Vheel As Single
        Public ma() As Single 'moment arm
```

```
        Public M() As Single 'moment
        Public F() As Single 'force
        Public FSo As Single
        Public OK_o As Boolean
        Public OK_vmax As Boolean
        Public OK_vmin As Boolean
        Public Sub New(ByVal inp As MVo)
            With Me
                .A_base = inp.A_base
                .B_base = inp.B_base
                .c_base = inp.c_base
                .e_base = inp.e_base
                .EMo = inp.EMo
                .EMr = inp.EMr
                .EV_base = inp.EV_base
                .F = inp.F.Clone()
                .FSo = inp.FSo
                .I_base = inp.I_base
                .M = inp.M.Clone()
                .M_base = inp.M_base
                .ma = inp.ma.Clone()
                .OK_o = inp.OK_o
                .OK_vmax = inp.OK_vmax
                .OK_vmin = inp.OK_vmin
                .Vheel = inp.Vheel
                .Vtoe = inp.Vtoe
                .x_base = inp.x_base
            End With
        End Sub
        Public Sub New()
        End Sub
    End Class
    <Serializable()> Public Class stab_geom_input_data
        'inputs
        Public Ks As Single
        Public Kr As Single
        Public Kst As Single  'needed for sliding (no need for uplift)
        Public delta As Single  'delta sill value for stillb
        Public mh_delta As Single   ' needed for sliding (no need for uplift)
        Public creep_path() As c_point
        Public str_start As Integer  'start of the structure(whole)(need for sliding and overturn)
        Public sb_start As Integer
        Public sb_end As Integer
        Public Ssb As Single    'settling basin slope ; needed only for settling basin, because for stilling basin it is
zero (horizantal)
        Public Sub New(ByVal inp As stab_geom_input_data)
            With Me
                Dim i As Integer
                For i = 0 To .creep_path.GetUpperBound(0) 'exact copy of the object array
                    .creep_path(i) = New c_point(inp.creep_path(i))
                Next
                .delta = inp.delta
                .Kr = inp.Kr
                .Ks = inp.Ks
                .Kst = inp.Kst
                .mh_delta = inp.mh_delta
                .sb_end = inp.sb_end
                .sb_start = inp.sb_start
                .Ssb = inp.Ssb
                .str_start = inp.str_start
            End With
```

```
        End Sub
        Public Sub New()
        End Sub
    End Class
    <Serializable()> Public Class stab_mtrl_input_data   'material input data
        Public gconc As Single
        Public gwater As Single
        Public Sallw_cf As Single  'allowable shear stress btw conc and found
        Public Callf As Single  'allowable foundation stress (for sidewalls)
        Public Cac As Single  'allowable comp stress for concrete
        Public Caf As Single   'allowable comp stress for foundation
        Public kh As Single  'hor seismic earthq coeff.
        Public kv As Single  'ver seismic eq coeff.
        Public Callw As Single  'foundation allowable stress
        Public f As Single  ' friction coeff btw soil and foundation
        Public ured_perc As Single  'uplift reduction percentage when drains added (in floating point
representation, not in percentage)
        Public gdry As Single 'dry unit weight of soil
        Public gsat As Single 'saturated unit weight of soil
        Public teta As Single  'angle of repose of the soil (in degrees)
        Public alfa As Single  'earth inclination at sidewalls (zero for hor)
        Public Sub New(ByVal inp As stab_mtrl_input_data)
            With Me
                .alfa = inp.alfa
                .Cac = inp.Cac
                .Caf = inp.Caf
                .Callf = inp.Callf
                .Callw = inp.Callw
                .f = inp.f
                .gconc = inp.gconc
                .gdry = inp.gdry
                .gsat = inp.gsat
                .gwater = inp.gwater
                .kh = inp.kh
                .kv = inp.kv
                .Sallw_cf = inp.Sallw_cf
                .teta = inp.teta
                .ured_perc = inp.ured_perc
            End With
        End Sub
        Public Sub New()
        End Sub
    End Class
    <Serializable()> Public Class stab_Fs_input_data
        Public Fsu As Single  'factor safety against uplift
        Public FSs As Single  'factor safety against sliding
        Public FSss As Single  'factor of safety against shear and sliding
        Public FSo As Single 'factor of safety against overturning
        Public Vmax As Single
        Public Vmin As Single
        Public FSo_sw As Single 'factor of safety for sidewalls
        Public FSs_sw As Single 'factor of safety for sidewalls
        Public Vmax_sw As Single
        Public Vmin_sw As Single
        Public Sub New(ByVal inp As stab_Fs_input_data)
            With Me
                Me.FSo = inp.FSo
                Me.FSo_sw = inp.FSo_sw
                Me.FSs = inp.FSs
                Me.FSs_sw = inp.FSs_sw
                Me.FSss = inp.FSss
```

```
            Me.Fsu = inp.Fsu
            Me.Vmax = inp.Vmax
            Me.Vmax_sw = inp.Vmax_sw
            Me.Vmin = inp.Vmin
            Me.Vmin_sw = inp.Vmin_sw
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
  <Serializable()> Public Class stab_sidewall_input_data
    Public Kus As Single
    Public y2max As Single
    Public tc As Single
    Public tc_base As Single
    Public El_base As Single 'need to determine the base elev of ret wall; this is simply stillbas base elev.
    Public t1 As Single
    Public t2 As Single
    Public t3 As Single
    Public mh_free As Single 'slope where sidewall is free (no earth exist)
    Public gwd As Single 'ground water depth from soil surface
    Public fsoil As Single 'freeboard from soil (earth side) if no freeboard =0
    Public q_surch As Single
    Public coulomb_type As Boolean
    Public change_dim_type As Byte
    Public Sub New(ByVal inp As stab_sidewall_input_data)
        With Me
            .change_dim_type = inp.change_dim_type
            .coulomb_type = inp.coulomb_type
            .El_base = inp.El_base
            .fsoil = inp.fsoil
            .gwd = inp.gwd
            .Kus = inp.Kus
            .mh_free = inp.mh_free
            .q_surch = inp.q_surch
            .t1 = inp.t1
            .t2 = inp.t2
            .t3 = inp.t3
            .tc = inp.tc
            .tc_base = inp.tc_base
            .y2max = inp.y2max
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
#End Region
#Region "Classes"
  <Serializable()> Public Class seepage_analysis
#Region "Private variables"
    'inputs
    Private profile() As String 'no need for comp, need for other
    Private C As Single     'relative permeability
    Private K() As Single   'u/s water level for various discharges
    Private Kd() As Single  'd/s tailwater level for various discharges
    Private Kr As Single    ' d/s riprap(tailwater) thalweg elevation
    Private Ks As Single    'spillway crest elevation
    Private creep_path() As c_point   'creep_path points determining creep path
    'outputs
    Private H_overf() As Single   'net head for overflowing cases
    Private H_funtw As Single      'net head for full u/s no tailwater case
```

```
    Private Hnet As Single        'net critic (max) head for all cases above: overflowing cases + full u/s no tw
case
    Private satisfactory As Boolean    'if minimum creep length for no piping was satisfied or not
    Private Lcr As Single   'creep length
    Private ELx() As Single
    Private Function Hmax(ByVal H1() As Single, ByVal H2 As Single) As Single
        Dim temp() As Single = H1.Clone()
        Array.Sort(temp)
        Return (Max(temp(temp.GetUpperBound(0)), H2))
    End Function
#End Region
#Region "Class interface"
    Private Sub compute()
        Dim i As Integer
        Dim temp(0) As c_point 'temp array of points for creep path and weight of body
        'overflowing cases
        For i = 0 To K.GetUpperBound(0)
            H_overf(i) = K(i) - Kd(i)
        Next
        'full u/s no tw case
        H_funtw = Ks - Kr
        'ceep length calculation
        Lcr = f_Lcreep(creep_path)
        'max head (critical head)
        Hnet = Hmax(H_overf, H_funtw)
        'ELx calculation
        ELx(0) = 0 'initial point
        temp(0) = New c_point(creep_path(0).x, creep_path(0).y) 'recall no change to temp, otherwise, if temp
is changed, creep_path values changes; think as pointer logic
        For i = 1 To creep_path.GetUpperBound(0)
            ReDim Preserve temp(i)
            temp(i) = New c_point(creep_path(i).x, creep_path(i).y)

            ELx(i) = f_Lcreep(temp)
        Next
        If Lcr >= C * Hnet Then
            satisfactory = True
        Else
            satisfactory = False
        End If
    End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property profile_pro() As String()
        Get
            Return profile
        End Get
    End Property
    Public ReadOnly Property ELx_pro() As Single()
        Get
            Return ELx
        End Get
    End Property
    Public ReadOnly Property inp_creep_path_pro() As c_point()
        Get
            Return creep_path
        End Get
    End Property
    Public ReadOnly Property inp_Ks_pro() As Single
        Get
            Return Ks
```

```
            End Get
        End Property
        Public ReadOnly Property inp_Kr_pro() As Single
            Get
                Return Kr
            End Get
        End Property
        Public ReadOnly Property inp_Kd_pro() As Single()
            Get
                Return Kd
            End Get
        End Property
        Public ReadOnly Property inp_K_pro() As Single()
            Get
                Return K
            End Get
        End Property
        Public ReadOnly Property inp_C_pro() As Single
            Get
                Return C
            End Get
        End Property
        Public ReadOnly Property H_overf_pro() As Single()
            Get
                Return H_overf
            End Get
        End Property
        Public ReadOnly Property Hnet_pro() As Single
            Get
                Return Hnet
            End Get
        End Property
        Public ReadOnly Property H_funtw_pro() As Single
            Get
                Return H_funtw
            End Get
        End Property
        Public ReadOnly Property satisfactory_pro() As Boolean
            Get
                Return satisfactory
            End Get
        End Property
        Public ReadOnly Property Lcr_pro() As Single
            Get
                Return Lcr
            End Get
        End Property
        Public ReadOnly Property CH_pro() As Single
            Get
                Return C * Hnet
            End Get
        End Property
#End Region
#Region "Constructors"
        Public Sub New(ByVal inp_C As Single, ByVal inp_K() As Single, ByVal inp_Kd() As Single, ByVal
inp_Ks As Single, ByVal inp_Kr As Single, ByVal inp_creep_path() As c_point, ByVal inp_profile() As
String)
            profile = inp_profile
            C = inp_C
            K = inp_K
            Kd = inp_Kd
```

```
            Kr = inp_Kr
            Ks = inp_Ks
            creep_path = inp_creep_path
            ReDim H_overf(inp_K.GetUpperBound(0))
            ReDim ELx(inp_creep_path.GetUpperBound(0))
            Me.compute()
        End Sub
#End Region
    End Class
    <Serializable()> Public Class stab_uplift_sb
        '**---------------------------------------------------------------------**
        '**  This class can be used for both settling basin and stilling basin   **
        '**  For settling basin-> Ssb must be input                              **
        '**  For stilling basin-> Ssb=0                                          **
        '**  Ls determined automatically by sb_start and sb_end data             **
        '**  Ssb imp for (Ls*Ssb); in order to find settl basin start el         **
        '**  for stilling basin; it is horizantal; no need                       **
        '**  Kr: d/s elev of settlbas (for settlbas)                             **
        '**  Kr: riprap sect elev (stillbas)                                     **
        '----------------------------------------------------------------------**
        '**  Ssb: stilling/settling basin upper slope (for stillbas Ssb=0 (hor)  **
        '----------------------------------------------------------------------**
        '**  NOTE:                                                               **
        '** last place to change the geom for stab because following sliding and **
        '** overturning calculated by cutting the cutoffs of the actual geometry **
        '** Therefore; vol computations of base are made here.......             **
        '**---------------------------------------------------------------------**
#Region "Private variables"
        'input
        Private stillbas_type As Boolean  'if structure is stillbas=true elseif settlbas =false
        Private input_geom As stab_geom_input_data
        Private gwater As Single
        Private gconc As Single
        Private ured_perc As Single
        Private FSu As Single
        'outputs
        Private ELx() As Single
        Private hx() As Single
        Private shead() As Single
        Private ux() As Single
        Private Lcr As Single  'creep length
        Private Hnet As Single  'net head
        Private hl_per_Lx As Single
        Private Fu As Single 'uplift force
        Private Wa As Single 'weight of body
        Private FSu_comp As Single 'computed factor of safety
        Private Elsb_ds As Single  'upper elevation of the downstream of stilling/settling basin
        Private Elsb_us As Single  'upper elevation of the upstream of stilling/settling basin
        Private satisfactory As Boolean 'if satisfactory, it is true else not
        Private drains_add As Boolean 'if drains_add needed it is true else not
        Private FSu_final As Single  'after the uplift reduction (if drains added)
        Private Fu_final As Single  ' after drains added
#End Region
#Region "Class interface"
        Private Sub compute()
            Dim i As Integer
            Dim temp(0) As c_point 'temp array of points for creep path and weight of body
            With input_geom
                If stillbas_type = False Then
                    ReDim Preserve .creep_path(.sb_end + 1)
                    ReDim ELx(.creep_path.GetUpperBound(0))
```

```
            ReDim hx(.creep_path.GetUpperBound(0))
            ReDim shead(.creep_path.GetUpperBound(0))
            ReDim ux(.creep_path.GetUpperBound(0))
            .creep_path(.sb_end + 1) = New c_point(.creep_path(.sb_end).x, .creep_path(.sb_end).y)
            .creep_path(.sb_end + 1).y = .Kr - .delta
            Hnet = .Ks - .creep_path(.sb_end + 1).y 'now the last creep point is this
        Else
            Hnet = .Ks - .Kr
        End If
        Lcr = f_Lcreep(.creep_path)
        hl_per_Lx = Hnet / Lcr
        'initial point
        ELx(0) = 0
        hx(0) = 0
        shead(0) = .Ks - .creep_path(0).y
        ux(0) = shead(0) - hx(0)
        temp(0) = New c_point(.creep_path(0).x, .creep_path(0).y)
        For i = 1 To .creep_path.GetUpperBound(0)
            ReDim Preserve temp(i)
            temp(i) = New c_point(.creep_path(i).x, .creep_path(i).y)
            ELx(i) = f_Lcreep(temp)
            hx(i) = hl_per_Lx * ELx(i)
            shead(i) = .Ks - .creep_path(i).y
            ux(i) = shead(i) - hx(i)
        Next
        'rest is same for settl and still bas
        'compute Fu and weight of body
        ReDim temp(Abs(.sb_end - .sb_start) + 3)
        Fu = 0
        For i = .sb_start To (.sb_end - 1)
            Fu = Fu + (ux(i) + ux(i + 1)) / 2 * gwater * (.creep_path(i + 1).x - .creep_path(i).x)
            temp(i - .sb_start) = New c_point(.creep_path(i).x, .creep_path(i).y)
        Next
        Fu_final = Fu '(no reduction yet,so Fu_red=Fu)
        Elsb_ds = .Kr - .delta
        Elsb_us = Elsb_ds + .Ssb * Abs(.creep_path(.sb_end).x - .creep_path(.sb_start).x)
        temp(.sb_end - .sb_start) = New c_point(.creep_path(.sb_end).x, .creep_path(.sb_end).y)
        temp(.sb_end - .sb_start + 1) = New c_point(.creep_path(.sb_end).x, Elsb_ds)
        temp(.sb_end - .sb_start + 2) = New c_point(.creep_path(.sb_start).x, Elsb_us)
        temp(.sb_end - .sb_start + 3) = New c_point(temp(0).x, temp(0).y) 'close the polygon
        Wa = f_poly_area(temp) * gconc  'kn/m for unit width of the canal
        FSu_comp = Wa / Fu   'kn/m
        FSu_final = FSu_comp
        If (FSu_comp >= FSu) Then
            satisfactory = True
            drains_add = False
        Else
            Fu_final = Fu * (1 - ured_perc)
            FSu_final = Wa / Fu_final
            drains_add = True
            If (FSu_final >= FSu) Then
                satisfactory = True
            Else
                satisfactory = False
            End If
        End If
    End With
End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property inp_stillbas_type_pro() As Boolean
```

```
            Get
                Return stillbas_type
            End Get
        End Property
        Public ReadOnly Property input_geom_pro() As stab_geom_input_data
            Get
                Return input_geom
            End Get
        End Property
        Public ReadOnly Property inp_gwater_pro() As Single
            Get
                Return gwater
            End Get
        End Property
        Public ReadOnly Property inp_gconc_pro() As Single
            Get
                Return gconc
            End Get
        End Property
        Public ReadOnly Property inp_ured_perc_pro() As Single
            Get
                Return ured_perc
            End Get
        End Property
        Public ReadOnly Property inp_Fsu_pro() As Single
            Get
                Return FSu
            End Get
        End Property
        'creep path to use at sliding and overturning analysis
        Public ReadOnly Property geom_for_so_pro() As stab_geom_input_data
            Get
                'hep pointer mantigi ile dusun...
                Dim geom_data As New stab_geom_input_data()
                Dim El_bottom As Single
                Dim i As Integer
                With input_geom
                    El_bottom = Min(.creep_path(.sb_start).y, .creep_path(.sb_end).y)
                End With
                With geom_data
                    .delta = input_geom.delta
                    .Kr = input_geom.Kr
                    .Ks = input_geom.Ks
                    .Kst = input_geom.Kst
                    .mh_delta = input_geom.mh_delta
                    .sb_end = input_geom.sb_end
                    .sb_start = input_geom.sb_start
                    .Ssb = input_geom.Ssb
                    .str_start = input_geom.str_start
                    ReDim .creep_path(input_geom.creep_path.GetUpperBound(0))
                    For i = 0 To .str_start
                        .creep_path(i) = New c_point(input_geom.creep_path(i).x, input_geom.creep_path(i).y)
                    Next
                    For i = .str_start + 1 To .creep_path.GetUpperBound(0) - 1
                        .creep_path(i) = New c_point(input_geom.creep_path(i).x, El_bottom)
                    Next
                    .creep_path(.creep_path.GetUpperBound(0)) = New
c_point(input_geom.creep_path(.creep_path.GetUpperBound(0)).x,
input_geom.creep_path(.creep_path.GetUpperBound(0)).y)
                End With
                Return geom_data
```

```
            End Get
        End Property
        Public ReadOnly Property Area_sb_pro() As Single
            Get
                With input_geom
                    Dim i As Integer
                    Dim area_cutoff_ds As Single
                    Dim geo_cutoff_ds(.creep_path.GetUpperBound(0) - .sb_end + 3) As c_point
                    For i = .sb_end To .creep_path.GetUpperBound(0)
                        geo_cutoff_ds(i - .sb_end) = .creep_path(i)
                    Next
                    geo_cutoff_ds(i - .sb_end) = geo_cutoff_ds(i - .sb_end - 1)
                    geo_cutoff_ds(i - .sb_end).x = geo_cutoff_ds(i - .sb_end - 1).x -
(.creep_path(.creep_path.GetUpperBound(0)).x - .creep_path(.sb_end).x - .delta * .mh_delta)
                    geo_cutoff_ds(i - .sb_end + 1) = New c_point(geo_cutoff_ds(i - .sb_end).x - .mh_delta * .delta,
Elsb_ds)
                    geo_cutoff_ds(i - .sb_end + 2) = geo_cutoff_ds(0)
                    area_cutoff_ds = f_poly_area(geo_cutoff_ds)
                    Return (Wa / gconc + area_cutoff_ds)
                End With
            End Get
        End Property
        Public ReadOnly Property Area_cutoff_us_pro() As Single 'body above cutoff (spillway sluiceway body)
not added here(will be added following modules)
            Get
                With input_geom
                    Dim i As Integer
                    Dim area_cutoff_us As Single
                    Dim geo_cutoff_us(.sb_start - (.str_start + 1) + 3) As c_point
                    For i = .str_start + 1 To .sb_start
                        geo_cutoff_us(i - (.str_start + 1)) = .creep_path(i)
                    Next
                    geo_cutoff_us(i - (.str_start + 1)) = geo_cutoff_us(i - (.str_start + 1) - 1)
                    geo_cutoff_us(i - (.str_start + 1)).y = Elsb_us
                    geo_cutoff_us(i - (.str_start + 1) + 1) = geo_cutoff_us(i - (.str_start + 1))
                    geo_cutoff_us(i - (.str_start + 1) + 1).x = geo_cutoff_us(0).x
                    geo_cutoff_us(i - (.str_start + 1) + 2) = geo_cutoff_us(0)
                    area_cutoff_us = f_poly_area(geo_cutoff_us)
                    Return area_cutoff_us
                End With
            End Get
        End Property
        Public ReadOnly Property Area_slab_tot_pro() As Single
            Get
                Return Area_sb_pro + Area_cutoff_us_pro
            End Get
        End Property
        Public ReadOnly Property ELx_pro() As Single()
            Get
                Return ELx
            End Get
        End Property
        Public ReadOnly Property L_blankets_pro() As Single
            Get
                With input_geom
                    Return Abs(.creep_path(0).x - .creep_path(.str_start).x)
                End With
            End Get
        End Property
        Public ReadOnly Property L_sheetpile_pro() As Single
            Get
```

```
            With input_geom
                Return Abs(.creep_path(0).y - .creep_path(1).y)
            End With
        End Get
    End Property
    Public ReadOnly Property L1_pro() As Single
        Get
            With input_geom
                Return Abs(.creep_path(.str_start + 1).x - .creep_path(.str_start + 2).x)
            End With
        End Get
    End Property
    Public ReadOnly Property Lcutoff_tot_pro() As Single
        Get
            With input_geom
                Return Abs(.creep_path(.str_start + 1).x - .creep_path(.sb_start).x)
            End With
        End Get
    End Property
    Public ReadOnly Property ux_pro() As Single()
        Get
            Return ux
        End Get
    End Property
    Public ReadOnly Property hx_pro() As Single()
        Get
            Return hx
        End Get
    End Property
    Public ReadOnly Property shead_pro() As Single()
        Get
            Return shead
        End Get
    End Property
    Public ReadOnly Property Lcr_pro() As Single
        Get
            Return Lcr
        End Get
    End Property
    Public ReadOnly Property Hnet_pro() As Single
        Get
            Return Hnet
        End Get
    End Property
    Public ReadOnly Property hl_per_Lx_pro() As Single
        Get
            Return hl_per_Lx
        End Get
    End Property
    Public ReadOnly Property Fu_pro() As Single
        Get
            Return Fu
        End Get
    End Property
    Public ReadOnly Property Wa_pro() As Single
        Get
            Return Wa
        End Get
    End Property
    Public ReadOnly Property Fsu_comp_pro() As Single
        Get
```

```
            Return FSu_comp
        End Get
    End Property
    Public ReadOnly Property Fsu_pro() As Single
        Get
            Return FSu
        End Get
    End Property
    Public ReadOnly Property Elsb_ds_pro() As Single
        Get
            Return Elsb_ds
        End Get
    End Property
    Public ReadOnly Property Elsb_us_pro() As Single
        Get
            Return Elsb_us
        End Get
    End Property
    Public ReadOnly Property tsb_us_pro() As Single
        Get
            With input_geom
                Return Elsb_us - .creep_path(.sb_start).y
            End With
        End Get
    End Property
    Public ReadOnly Property tsb_ds_pro() As Single
        Get
            With input_geom
                Return Elsb_ds - .creep_path(.sb_end).y
            End With
        End Get
    End Property
    Public ReadOnly Property satisfactory_pro() As Boolean
        Get
            Return satisfactory
        End Get
    End Property
    Public ReadOnly Property drains_add_pro() As Boolean
        Get
            Return drains_add
        End Get
    End Property
    Public ReadOnly Property Fsu_final_pro() As Single
        Get
            Return FSu_final
        End Get
    End Property
    Public ReadOnly Property Fu_final_pro() As Single
        Get
            Return Fu_final
        End Get
    End Property
#End Region
#Region "Constructors"
    Public Sub New(ByVal inp_stillbas_type As Boolean, ByVal input As stab_geom_input_data, ByVal
inp_gwater As Single, ByVal inp_gconc As Single, ByVal inp_FSu As Single, ByVal inp_ured_perc As
Single)
        stillbas_type = inp_stillbas_type
        input_geom = input
        FSu = inp_FSu
        gwater = inp_gwater
```

```
            gconc = inp_gconc
            ured_perc = inp_ured_perc
            With input_geom
                ReDim ELx(.creep_path.GetUpperBound(0))
                ReDim hx(.creep_path.GetUpperBound(0))
                ReDim shead(.creep_path.GetUpperBound(0))
                ReDim ux(.creep_path.GetUpperBound(0))
            End With
            Me.compute()
        End Sub
#End Region
    End Class
    <Serializable()> Public Class stab_sliding_and_overt
        'Assume that the spillway and apron is considered by neglecting the cutoff walls
        'and passive resistance
        'for sliding whole body with stilling basin and spillway is considered
        'for overturning only spillway body is considered.
#Region "Private variables"
        'inputs
        Private input_geom As stab_geom_input_data
        Private input_mtrl As stab_mtrl_input_data
        Private input_Fs As stab_Fs_input_data
        Private drains_add As Boolean  ' if drains added before(output of stab_uflift is input this time)
        Private mh_ogee As Single   'spillway d/s slope (ogee shape slope)
        Private tc As Single  'crest thickness of spillway
        Private crest_auto As Boolean  'crest thickness calculated automatically
        'outputs*******************************************
        'creep calculations
        Private Lcr As Single
        Private hl_per_Lx As Single
        Private Hnet As Single
        Private ELx() As Single
        Private hx() As Single
        Private shead() As Single
        Private ux() As Single
        'shear and sliding check 'full u/s no tailwater
        Private Fu As Single 'uplift force
        Private Fh As Single 'hydrostatic force
        Private Fw As Single 'dynamic hydrostatic force
        Private Fuh As Single 'hydrostatic force below sheetpile
        Private Fs As Single 'lateral active eart pressure force
        Private W As Single ' weight of the body
        Private Fdh As Single 'hor dynamic force
        Private Fdv As Single 'ver dynamic force
        Private gsub As Single 'gsub=gsat-gdry
        Private Ka As Single 'lateral active earth press coef
        Private Ashear As Single 'area of shear plane
        Private FSs_comp As Single
        Private FSss_comp As Single
        Private Ftot_h As Single
        Private Ftot_v As Single
        Private OK_s As Boolean  'sliding
        Private OK_ss As Boolean 'shear and sliding
        'for overturning of spillway wrt heel (full u/s no tailwater case)
        Private MVoheel As MVo 'no subscript for full u/s no tailwater; because it is the default case
        'for overturning of spillway wrt heel (empty reservoir case)
        Private MVoheel_eu As MVo
        'for overturning of spillway wrt toe (empty reservoir case)
        Private MVotoe_eu As MVo
#End Region
#Region "Class interface"
```

```
Private Sub compute_sliding()
    Dim i As Integer
    Dim xR As Single  'spillway toe hor dist
    Dim alfa As Single 'angle of spillw ogee slope
    Dim temp(0) As c_point 'temp array of points for creep path and weight of body
    With input_geom
        Hnet = .Ks - .Kr
        Lcr = f_Lcreep(.creep_path)
        hl_per_Lx = Hnet / Lcr
        'code repetition, (may need optimization in future)
        'initial point
        ELx(0) = 0
        hx(0) = 0
        shead(0) = .Ks - .creep_path(0).y
        ux(0) = shead(0) - hx(0)
        temp(0) = New c_point(.creep_path(0).x, .creep_path(0).y)
        For i = 1 To .creep_path.GetUpperBound(0)
            ReDim Preserve temp(i)
            temp(i) = New c_point(.creep_path(i).x, .creep_path(i).y)
            ELx(i) = f_Lcreep(temp)
            hx(i) = hl_per_Lx * ELx(i)
            shead(i) = .Ks - .creep_path(i).y
            ux(i) = shead(i) - hx(i)
        Next
        'compute Fu
        Fu = input_mtrl.gwater * (ux(.str_start + 1) + ux(.creep_path.GetUpperBound(0) - 1)) / 2 *
Abs(.creep_path(.creep_path.GetUpperBound(0)).x - .creep_path(.str_start).x)
        'reduce the uplift if the draind added
        If drains_add Then Fu = Fu * (1 - input_mtrl.ured_perc)
        'compute Fuh
        Fuh = input_mtrl.gwater * (ux(.str_start) + ux(.str_start + 1)) / 2 * Abs(.creep_path(.str_start).y -
.creep_path(.str_start + 1).y)
        'compute Fh
        Fh = 1 / 2 * ((.Ks - .Kst) ^ 2) * input_mtrl.gwater
        'compute Fw  (vertical u/s face 0.7)
        Fw = 0.726 * 0.7 * input_mtrl.kh * input_mtrl.gwater * (.Ks - .Kst) ^ 2
        'compute Fs
        gsub = input_mtrl.gsat - input_mtrl.gwater
        Ka = (1 - Sin(input_mtrl.teta * 2 * PI / 360)) / (1 + Sin(input_mtrl.teta * 2 * PI / 360))
        Fs = 1 / 2 * input_mtrl.gwater * Ka * (.creep_path(.str_start).y - .creep_path(.str_start + 1).y) ^ 2
        'compute W
        ReDim temp(.creep_path.GetUpperBound(0) - .str_start + 6) ' for the determination of closed
polygon
        For i = 0 To (.creep_path.GetUpperBound(0) - .str_start)
            temp(i) = New c_point(.creep_path(.str_start + i).x, .creep_path(.str_start + i).y)
        Next
        i -= 1  'next ' gorunce i arttiriliyor, bu sebeple i bir azaltilmali
        temp(i + 1) = New c_point(temp(i).x - (Abs(.creep_path(.creep_path.GetUpperBound(0)).x -
.creep_path(.sb_end).x) - .delta * .mh_delta), temp(i).y)
        temp(i + 2) = New c_point(temp(i + 1).x - .delta * .mh_delta, temp(i + 1).y - .delta)
        temp(i + 3) = New c_point(temp(i + 2).x - Abs(.creep_path(.sb_end).x - .creep_path(.sb_start).x),
temp(i + 2).y)
        'may be modifed that R can be input in future
        If crest_auto Then  'crest thickness of spillway is not given
            alfa = Atan(1 / mh_ogee)
            xR = 0.5 * (.Ks - .Kst) * Tan(alfa / 2) 'assume that R=0.5*P ; to be modified
            temp(i + 4) = New c_point(temp(i + 3).x - xR - (.Ks - temp(i + 3).y) * mh_ogee - xR, .Ks)
        Else 'crest thickness is given
            temp(i + 4) = New c_point(temp(0).x + tc, .Ks)
        End If
        temp(i + 5) = New c_point(temp(0).x, temp(i + 4).y)
```

```
            temp(i + 6) = New c_point(temp(0).x, temp(0).y) 'close the polygon
            'crest thickness of the spillway
            tc = Abs(temp(i + 5).x - temp(i + 4).x)
            W = f_poly_area(temp) * input_mtrl.gconc
            'compute Fdh and Fdv
            Fdh = input_mtrl.kh * W
            Fdv = input_mtrl.kv * W
            Ftot_h = Fw + Fh + Fs + Fuh + Fdh
            Ftot_v = W - Fdv - Fu
            'FSs and FSss computed
            FSs_comp = input_mtrl.f * Ftot_v / Ftot_h
            Ashear = Abs(.creep_path(.str_start).x - .creep_path(.creep_path.GetUpperBound(0)).x) * 1 ' calc
made for 1 meter width
            FSss_comp = (input_mtrl.f * Ftot_v + 0.5 * Ashear * input_mtrl.Sallw_cf) / Ftot_h
            'checks
            If (FSs_comp >= input_Fs.FSs) Then
               OK_s = True
            Else
               OK_s = False
            End If
            If (FSss_comp >= input_Fs.FSss) Then
               OK_ss = True
            Else
               OK_ss = False
            End If
         End With
      End Sub
      Private Sub compute_overt()
         Dim i As Integer
         'note that forces always in the following order
         'Fw - 0
         'Fh - 1
         'Fs - 2
         'Fuh - 3
         'Fdh - 4
         'W - 5
         'Fdv - 6
         'Fu - 7
         With input_geom
            Dim temp(.sb_start - .str_start + 4) As c_point 'temp array of points for weight of spillway body
            For i = 0 To (.sb_start - .str_start)
               temp(i) = New c_point(.creep_path(.str_start + i).x, .creep_path(.str_start + i).y)
            Next
            temp(i) = New c_point(temp(i - 1).x, .creep_path(.creep_path.GetUpperBound(0)).y - .delta)
            temp(i + 1) = New c_point(temp(0).x + tc, .Ks)
            temp(i + 2) = New c_point(temp(0).x, .Ks)
            temp(i + 3) = New c_point(temp(0).x, temp(0).y) 'close the polygon
            'Fw-0
            MVoheel.F(0) = Fw
            MVoheel.ma(0) = 0.412 * (.Ks - .Kst) + Abs(temp(0).y - temp(1).y)
            'Fh-1
            MVoheel.F(1) = Fh
            MVoheel.ma(1) = (.Ks - .Kst) / 3 + Abs(temp(0).y - temp(1).y)
            'Fs-2
            MVoheel.F(2) = Fs
            MVoheel.ma(2) = Abs(temp(0).y - temp(1).y) / 3
            'Fuh-3
            MVoheel.F(3) = Fuh
            MVoheel.ma(3) = f_trap_centr_d_from_b(ux(.sb_start + 1), ux(.str_start), Abs(temp(0).y -
temp(1).y))
            'W-5
```

```
            MVoheel.F(5) = f_poly_area(temp) * input_mtrl.gconc * 1 'for 1 meter
            MVoheel.ma(5) = Abs(f_poly_centr(temp).x - temp(.sb_start - .str_start).x)
            'Fdh-4
            MVoheel.F(4) = MVoheel.F(5) * input_mtrl.kh
            MVoheel.ma(4) = Abs(f_poly_centr(temp).y - temp(.sb_start - .str_start).y)
            'Fdv-6
            MVoheel.F(6) = MVoheel.F(5) * input_mtrl.kv
            MVoheel.ma(6) = Abs(f_poly_centr(temp).x - temp(.sb_start - .str_start).x)
            'Fu-7
            MVoheel.F(7) = (ux(.str_start + 1) + ux(.sb_start)) / 2 * Abs(temp(.sb_start - .str_start).x -
temp(1).x) * input_mtrl.gwater
            MVoheel.ma(7) = Abs(temp(.sb_start - .str_start).x - temp(1).x) -
f_trap_centr_d_from_b(ux(.str_start + 1), ux(.sb_start), Abs(temp(.sb_start - .str_start).x - temp(1).x))
            If drains_add = True Then MVoheel.F(7) = (1 - input_mtrl.ured_perc) * MVoheel.F(7)
            MVoheel.EMo = 0
            For i = 0 To 7
               MVoheel.M(i) = MVoheel.F(i) * MVoheel.ma(i)
               MVoheel.EMo = MVoheel.EMo + MVoheel.M(i)
            Next
            MVoheel.EMo = MVoheel.EMo - MVoheel.M(5)
            MVoheel.EMr = MVoheel.M(5)
            MVoheel.FSo = MVoheel.EMr / MVoheel.EMo
            If MVoheel.FSo >= input_Fs.FSo Then
               MVoheel.OK_o = True
            Else
               MVoheel.OK_o = False
            End If
            'Note:remember arraya are objects; reference type(not value type) MVotoe_eu=MVoheel behaves
like pointer equality; so that if one change, the other also changes
            'empty u/s case wrt toe
            For i = 0 To MVoheel.M.GetUpperBound(0)
               MVotoe_eu.F(i) = MVoheel.F(i)
               MVotoe_eu.ma(i) = MVoheel.ma(i)
            Next
            MVotoe_eu.F(0) = 0
            MVotoe_eu.F(1) = 0
            MVotoe_eu.F(3) = 0
            MVotoe_eu.F(7) = 0
            MVotoe_eu.ma(5) = Abs(f_poly_centr(temp).x - temp(1).x)
            MVotoe_eu.ma(6) = Abs(f_poly_centr(temp).x - temp(1).x)
            For i = 0 To 7
               MVotoe_eu.M(i) = MVotoe_eu.F(i) * MVotoe_eu.ma(i)
            Next
            MVotoe_eu.EMo = MVotoe_eu.M(4) + MVotoe_eu.M(6)
            MVotoe_eu.EMr = MVotoe_eu.M(2) + MVotoe_eu.M(5)
            MVotoe_eu.FSo = MVotoe_eu.EMr / MVotoe_eu.EMo
            If MVotoe_eu.FSo >= input_Fs.FSo Then
               MVotoe_eu.OK_o = True
            Else
               MVotoe_eu.OK_o = False
            End If
            'Note:remember arraya are objects; reference type(not value type) MVotoe_eu=MVoheel behaves
like pointer equality; so that if one change, the other also changes
            'empty u/s case wrt heel
            For i = 0 To MVoheel.M.GetUpperBound(0)
               MVoheel_eu.F(i) = MVoheel.F(i)
               MVoheel_eu.ma(i) = MVoheel.ma(i)
            Next
            MVoheel_eu.F(0) = 0
            MVoheel_eu.F(1) = 0
            MVoheel_eu.F(3) = 0
```

```
            MVoheel_eu.F(7) = 0
            For i = 0 To 7
               MVoheel_eu.M(i) = MVoheel_eu.F(i) * MVoheel_eu.ma(i)
            Next
            MVoheel_eu.EMo = MVoheel_eu.M(2) + MVoheel_eu.M(4) + MVoheel_eu.M(6)
            MVoheel_eu.EMr = MVoheel_eu.M(5)
            MVoheel_eu.FSo = MVoheel_eu.EMr / MVoheel_eu.EMo
            If MVoheel_eu.FSo >= input_Fs.FSo Then
               MVoheel_eu.OK_o = True
            Else
               MVoheel_eu.OK_o = False
            End If
         End With
      End Sub
      Private Sub compute_base_pressures()
         With input_geom
            'full u/s no tailwater case wrt heel
            MVoheel.B_base = Abs(.creep_path(.str_start + 1).x - .creep_path(.sb_start).x)
            MVoheel.EV_base = MVoheel.F(5) - MVoheel.F(6) - MVoheel.F(7)
            MVoheel.x_base = (MVoheel.EMr - MVoheel.EMo) / MVoheel.EV_base
            MVoheel.e_base = MVoheel.B_base / 2 - MVoheel.x_base
            MVoheel.c_base = MVoheel.B_base / 2
            MVoheel.M_base = MVoheel.EV_base * MVoheel.e_base
            MVoheel.I_base = MVoheel.B_base ^ 3 / 12
            MVoheel.A_base = MVoheel.B_base * 1 'for unit width
            MVoheel.Vheel = MVoheel.EV_base / MVoheel.A_base + MVoheel.M_base * MVoheel.c_base /
MVoheel.I_base
            MVoheel.Vtoe = MVoheel.EV_base / MVoheel.A_base - MVoheel.M_base * MVoheel.c_base /
MVoheel.I_base
            If Max(MVoheel.Vtoe, MVoheel.Vheel) <= input_Fs.Vmax Then
               MVoheel.OK_vmax = True
            Else
               MVoheel.OK_vmax = False
            End If
            If Min(MVoheel.Vtoe, MVoheel.Vheel) >= input_Fs.Vmin Then
               MVoheel.OK_vmin = True
            Else
               MVoheel.OK_vmin = False
            End If
            'empty u/s case (wrt toe)***********************************
            MVotoe_eu.B_base = Abs(.creep_path(.str_start + 1).x - .creep_path(.sb_start).x)
            MVotoe_eu.EV_base = MVotoe_eu.F(5) - MVotoe_eu.F(6)
            MVotoe_eu.x_base = (MVotoe_eu.EMr - MVotoe_eu.EMo) / MVotoe_eu.EV_base
            MVotoe_eu.e_base = MVotoe_eu.B_base / 2 - MVotoe_eu.x_base
            MVotoe_eu.c_base = MVotoe_eu.B_base / 2
            MVotoe_eu.M_base = MVotoe_eu.EV_base * MVotoe_eu.e_base
            MVotoe_eu.I_base = MVotoe_eu.B_base ^ 3 / 12
            MVotoe_eu.A_base = MVotoe_eu.B_base * 1 'for unit width
            MVotoe_eu.Vtoe = MVotoe_eu.EV_base / MVotoe_eu.A_base + MVotoe_eu.M_base *
MVotoe_eu.c_base / MVotoe_eu.I_base
            MVotoe_eu.Vheel = MVotoe_eu.EV_base / MVotoe_eu.A_base - MVotoe_eu.M_base *
MVotoe_eu.c_base / MVotoe_eu.I_base
            If Max(MVotoe_eu.Vtoe, MVotoe_eu.Vheel) <= input_Fs.Vmax Then
               MVotoe_eu.OK_vmax = True
            Else
               MVotoe_eu.OK_vmax = False
            End If
            If Min(MVotoe_eu.Vtoe, MVotoe_eu.Vheel) >= input_Fs.Vmin Then
               MVotoe_eu.OK_vmin = True
            Else
               MVotoe_eu.OK_vmin = False
```

```
            End If
            'empty u/s case (wrt heel)*************************************
            MVoheel_eu.B_base = Abs(.creep_path(.str_start + 1).x - .creep_path(.sb_start).x)
            MVoheel_eu.EV_base = MVoheel_eu.F(5) - MVoheel_eu.F(6)
            MVoheel_eu.x_base = (MVoheel_eu.EMr - MVoheel_eu.EMo) / MVoheel_eu.EV_base
            MVoheel_eu.e_base = MVoheel_eu.B_base / 2 - MVoheel_eu.x_base
            MVoheel_eu.c_base = MVoheel_eu.B_base / 2
            MVoheel_eu.M_base = MVoheel_eu.EV_base * MVoheel_eu.e_base
            MVoheel_eu.I_base = MVoheel_eu.B_base ^ 3 / 12
            MVoheel_eu.A_base = MVoheel_eu.B_base * 1 'for unit width
            MVoheel_eu.Vheel = MVoheel_eu.EV_base / MVoheel_eu.A_base + MVoheel_eu.M_base *
MVoheel_eu.c_base / MVoheel_eu.I_base
            MVoheel_eu.Vtoe = MVoheel_eu.EV_base / MVoheel_eu.A_base - MVoheel_eu.M_base *
MVoheel_eu.c_base / MVoheel_eu.I_base
            If Max(MVoheel_eu.Vtoe, MVoheel_eu.Vheel) <= input_Fs.Vmax Then
                MVoheel_eu.OK_vmax = True
            Else
                MVoheel_eu.OK_vmax = False
            End If
            If Min(MVoheel_eu.Vtoe, MVoheel_eu.Vheel) >= input_Fs.Vmin Then
                MVoheel_eu.OK_vmin = True
            Else
                MVoheel_eu.OK_vmin = False
            End If
        End With
    End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property input_geom_pro() As stab_geom_input_data
        Get
            Return input_geom
        End Get
    End Property
    Public ReadOnly Property input_mtrl_pro() As stab_mtrl_input_data
        Get
            Return input_mtrl
        End Get
    End Property
    Public ReadOnly Property input_Fs_pro() As stab_Fs_input_data
        Get
            Return input_Fs
        End Get
    End Property
    Public ReadOnly Property inp_drains_add_pro() As Boolean
        Get
            Return drains_add
        End Get
    End Property
    Public ReadOnly Property inp_mh_ogee_pro() As Single
        Get
            Return mh_ogee
        End Get
    End Property
    Public ReadOnly Property inp_tc_pro() As Single
        Get
            Return tc
        End Get
    End Property
    Public ReadOnly Property inp_crest_auto_pro() As Boolean
        Get
            Return crest_auto
```

```
    End Get
End Property
Public ReadOnly Property Area_conc_splw_pro() As Single
    Get
        'F(5) is the weight of the body of splw
        Return (MVoheel.F(5) / Me.input_mtrl.gconc)
    End Get
End Property
Public ReadOnly Property MVoheel_pro() As MVo
    Get
        Return MVoheel
    End Get
End Property
Public ReadOnly Property MVoheel_eu_pro() As MVo
    Get
        Return MVoheel_eu
    End Get
End Property
Public ReadOnly Property MVotoe_eu_pro() As MVo
    Get
        Return MVotoe_eu
    End Get
End Property
Public ReadOnly Property FSo_pro() As Single
    Get
        Return input_Fs.FSo
    End Get
End Property
Public ReadOnly Property Vmax_pro() As Single
    Get
        Return input_Fs.Vmax
    End Get
End Property
Public ReadOnly Property Vmin_pro() As Single
    Get
        Return input_Fs.Vmin
    End Get
End Property
Public ReadOnly Property tc_pro() As Single
    Get
        Return tc
    End Get
End Property
Public ReadOnly Property crest_auto_pro() As Boolean
    Get
        Return crest_auto
    End Get
End Property
Public ReadOnly Property mh_ogee_pro() As Boolean
    Get
        Return mh_ogee
    End Get
End Property
Public ReadOnly Property ELx_pro() As Single()
    Get
        Return ELx
    End Get
End Property
Public ReadOnly Property ux_pro() As Single()
    Get
        Return ux
```

```
    End Get
End Property
Public ReadOnly Property hx_pro() As Single()
    Get
        Return hx
    End Get
End Property
Public ReadOnly Property shead_pro() As Single()
    Get
        Return shead
    End Get
End Property
Public ReadOnly Property Lcr_pro() As Single
    Get
        Return Lcr
    End Get
End Property
Public ReadOnly Property Hnet_pro() As Single
    Get
        Return Hnet
    End Get
End Property
Public ReadOnly Property hl_per_Lx_pro() As Single
    Get
        Return hl_per_Lx
    End Get
End Property
Public ReadOnly Property Fu_pro() As Single
    Get
        Return Fu
    End Get
End Property
Public ReadOnly Property Fh_pro() As Single
    Get
        Return Fh
    End Get
End Property
Public ReadOnly Property Fw_pro() As Single
    Get
        Return Fw
    End Get
End Property
Public ReadOnly Property Fuh_pro() As Single
    Get
        Return Fuh
    End Get
End Property
Public ReadOnly Property Fs_pro() As Single
    Get
        Return Fs
    End Get
End Property
Public ReadOnly Property Fdh_pro() As Single
    Get
        Return Fdh
    End Get
End Property
Public ReadOnly Property Fdv_pro() As Single
    Get
        Return Fdv
    End Get
```

```
End Property
Public ReadOnly Property W_pro() As Single
    Get
        Return W
    End Get
End Property
Public ReadOnly Property gsub_pro() As Single
    Get
        Return gsub
    End Get
End Property
Public ReadOnly Property Ka_pro() As Single
    Get
        Return Ka
    End Get
End Property
Public ReadOnly Property Ashear_pro() As Single
    Get
        Return Ashear
    End Get
End Property
Public ReadOnly Property Ftot_h_pro() As Single
    Get
        Return Ftot_h
    End Get
End Property
Public ReadOnly Property Ftot_v_pro() As Single
    Get
        Return Ftot_v
    End Get
End Property
Public ReadOnly Property FSs_pro() As Single
    Get
        Return input_Fs.FSs
    End Get
End Property
Public ReadOnly Property FSss_pro() As Single
    Get
        Return input_Fs.FSss
    End Get
End Property
Public ReadOnly Property FSs_comp_pro() As Single
    Get
        Return FSs_comp
    End Get
End Property
Public ReadOnly Property FSss_comp_pro() As Single
    Get
        Return FSss_comp
    End Get
End Property
Public ReadOnly Property OK_s_pro() As Boolean
    Get
        Return OK_s
    End Get
End Property
Public ReadOnly Property OK_ss_pro() As Boolean
    Get
        Return OK_ss
    End Get
End Property
```

```
        Public ReadOnly Property drains_add_pro() As Boolean
            Get
                Return drains_add
            End Get
        End Property
#End Region
#Region "Constructors"
        'if crest thickness is calculated automatically
        Public Sub New(ByVal input1 As stab_geom_input_data, ByVal input2 As stab_mtrl_input_data, ByVal
input3 As stab_Fs_input_data, ByVal inp_drains_add As Boolean, ByVal inp_mh_ogee As Single, ByVal
inp_tc As Single, ByVal inp_crest_auto As Boolean)
            input_geom = input1
            input_mtrl = input2
            input_Fs = input3
            drains_add = inp_drains_add
            crest_auto = inp_crest_auto 'if crest_auto=true ; tc not impartant, mh_ogee important, otherwise only tc
is important, mh_ogee not imp
            mh_ogee = inp_mh_ogee
            tc = inp_tc
            With input_geom
                ReDim ELx(.creep_path.GetUpperBound(0))
                ReDim hx(.creep_path.GetUpperBound(0))
                ReDim shead(.creep_path.GetUpperBound(0))
                ReDim ux(.creep_path.GetUpperBound(0))
            End With
            MVoheel = New MVo()
            ReDim MVoheel.F(7)
            ReDim MVoheel.ma(7)
            ReDim MVoheel.M(7)
            MVotoe_eu = New MVo()
            ReDim MVotoe_eu.F(7)
            ReDim MVotoe_eu.ma(7)
            ReDim MVotoe_eu.M(7)
            MVoheel_eu = New MVo()
            ReDim MVoheel_eu.F(7)
            ReDim MVoheel_eu.ma(7)
            ReDim MVoheel_eu.M(7)
            Me.compute_sliding()
            Me.compute_overt()
            Me.compute_base_pressures()
        End Sub
#End Region
    End Class
    <Serializable()> Public Class stab_sidewalls
        'iteration limits
        Public Shared max_iter_dim As Integer = 500 'for changing dim max iteration limits
#Region "Private variables"
        'inputs
        Private change_dim_type As Byte   'if Bsw is increased in order to satisfy safety
        Private beta, alfa, teta As Single 'beta: earthside slope in degrees
        Private gdry, gsat, gsub, gw, gconc As Single
        Private f As Single 'friction factor  'f=tanS ; S=atan(f)
        Private Kus As Single
        Private y2max As Single
        Private tc As Single
        Private tc_base As Single
        Private El_base As Single 'need to determine the base elev of ret wall; this is simply stillbas base elev.
        Private t1 As Single
        Private t2 As Single

        Private t3 As Single
```

```
Private mh_free As Single 'slope where sidewall is free (no earth exist)
Private El_gwt As Single 'ground water table elevation
Private fsoil As Single 'freeboard from soil (earth side) if no freeboard =0
Private q_surch As Single
Private coulomb_type As Boolean
Private Fso_sw As Single
Private FSs_sw As Single
Private Vmax_sw As Single
Private Vmin_sw As Single
'outputs
Private Bsw As Single
Private mh_sw As Single  'for determining sidewall geometry at earthfill side
Private Ka As Single
Private P1, P2 As Single
Private P_angle_h As Single  'for P1 and P2 force angle with horizantal in degrees

Private S As Single
Private Ksw As Single
Private MVo_toe As MVo 'pointer (it is initialized at constructor)
Private Ftot_h As Single
Private Ftot_v As Single
Private FSs_comp As Single
Private OK_s As Boolean
Private error_iter As Boolean
'index of forces in the array................
'P1h - 0
'P2h - 1
'Fh_ds - 2
'P1v - 3
'P2v - 4
'Wb - 5
'Wdry - 5
'Wsat - 7
'Fu - 8
'..........................................
Private Sub compute_sliding_overt()
    Dim temp_b(8) As c_point 'for weight of the sidewall body
    Dim temp_s(4) As c_point  'for weight of the soils
    Dim i As Integer
    With MVo_toe
        'structure definition; ccw
        temp_b(0) = New c_point(0, El_base) 'heel point
        temp_b(1) = New c_point(Bsw, temp_b(0).y)
        temp_b(2) = New c_point(temp_b(1).x, temp_b(1).y + t1)
        temp_b(3) = New c_point(temp_b(2).x - t3, temp_b(2).y)
        temp_b(4) = New c_point(temp_b(3).x - (Ksw - Kus) * mh_sw, Ksw)
        temp_b(5) = New c_point(temp_b(4).x - tc, Ksw)
        temp_b(6) = New c_point(t2, Kus)
        temp_b(7) = New c_point(0, Kus)
        temp_b(8) = New c_point(temp_b(0).x, temp_b(0).y)
        'angles must be in radians in order to compute cos values
        S = Atan(f)
        beta = (Atan(1 / mh_sw))
        gsub = gsat - gw
        alfa = alfa * 2 * PI / 360
        teta = teta * 2 * PI / 360
        'Wb
        .F(5) = gconc * f_poly_area(temp_b)
        .ma(5) = f_poly_centr(temp_b).x - temp_b(0).x
        'Fh_ds
        .F(2) = 1 / 2 * gw * (El_gwt - temp_b(1).y) ^ 2
```

```
.ma(2) = (El_gwt - temp_b(1).y) / 3
'Fu
.F(8) = 1 / 2 * Bsw * gw * (El_gwt - temp_b(1).y)
.ma(8) = 2 / 3 * Bsw
'Ka
If coulomb_type = True Then
    Ka = Sin(beta + teta) ^ 2 / (Sin(beta) ^ 2 * Sin(beta - S) * (1 + Sqrt(Sin(teta + S) * Sin(teta - alfa) / (Sin(beta - S) * Sin(alfa + beta))) ^ 2))
    'weight of the soil is not considered in coulomb type
    'Wdry
    .F(6) = 0
    .ma(6) = 0
    'Wsat
    .F(7) = 0
    .ma(7) = 0
    P_angle_h = (90 - beta + S) * 2 * PI / 360
    P1 = 1 / 2 * Ka * (q_surch + gdry * (temp_b(4).y - fsoil - El_gwt)) * (temp_b(4).y - fsoil - El_gwt)
    P2 = ((q_surch + gdry * (temp_b(4).y - fsoil - El_gwt)) * Ka + (q_surch + gdry * (temp_b(4).y - fsoil - El_gwt) + gsub * (El_gwt - temp_b(1).y)) * Ka) / 2 * (El_gwt - temp_b(1).y)
    'P1h
    .F(0) = P1 * Cos(P_angle_h)
    .ma(0) = El_gwt + (temp_b(4).y - fsoil - El_gwt) / 3 - temp_b(0).y
    'P1v
    .F(3) = P1 * Sin(P_angle_h)
    .ma(3) = temp_b(4).x + mh_sw * ((temp_b(4).y - fsoil - El_gwt) * 2 / 3 + fsoil) - temp_b(0).x
    'P2h
    .F(1) = P2 * Cos(P_angle_h)
    .ma(1) = f_trap_centr_d_from_b((q_surch + gdry * (temp_b(4).y - fsoil - El_gwt) + gsub * (El_gwt - temp_b(1).y)) * Ka, (q_surch + gdry * (temp_b(4).y - fsoil - El_gwt)) * Ka, (El_gwt - temp_b(1).y))
    'P2v
    .F(4) = P2 * Sin(P_angle_h)
    .ma(4) = temp_b(4).x + (temp_b(4).y - temp_b(1).y - .ma(1)) * mh_sw - temp_b(0).x
Else 'rankine
    Ka = (Cos(alfa) - Sqrt(Cos(alfa) ^ 2 - Cos(teta) ^ 2)) * Cos(alfa) / (Cos(alfa) + Sqrt(Cos(alfa) ^ 2 - Cos(teta) ^ 2))
    'Wsat
    temp_s(0) = New c_point(temp_b(3).x, temp_b(3).y)
    temp_s(1) = New c_point(temp_b(2).x, temp_b(2).y)
    temp_s(2) = New c_point(temp_b(1).x, El_gwt)
    temp_s(3) = New c_point(temp_b(4).x + mh_sw * (temp_b(4).y - El_gwt), El_gwt)
    temp_s(4) = New c_point(temp_s(0).x, temp_s(0).y)
    .F(7) = gsat * f_poly_area(temp_s)
    .ma(7) = f_poly_centr(temp_s).x - temp_b(0).x
    'Wdry
    temp_s(0) = New c_point(temp_s(3).x, temp_s(3).y)
    temp_s(1) = New c_point(temp_s(2).x, temp_s(2).y)
    temp_s(3).x = temp_b(4).x + mh_sw * fsoil
    temp_s(3).y = temp_b(4).y - fsoil
    temp_s(2) = New c_point(temp_b(1).x, temp_s(3).y + Tan(alfa * 2 * PI / 360) * (temp_b(1).x - temp_s(3).x))
    temp_s(4) = New c_point(temp_s(0).x, temp_s(0).y)
    .F(6) = gdry * f_poly_area(temp_s)
    .ma(6) = f_poly_centr(temp_s).x - temp_b(0).x
    P_angle_h = alfa
    P1 = 1 / 2 * Ka * (q_surch + gdry * (temp_s(2).y - temp_s(1).y)) * (temp_s(2).y - temp_s(1).y)
    P2 = ((q_surch + gdry * (temp_s(2).y - temp_s(1).y)) * Ka + (q_surch + gdry * (temp_s(2).y - temp_s(1).y) + gsub * (temp_s(1).y - temp_b(1).y)) * Ka) / 2 * (temp_s(1).y - temp_b(1).y)
    'P1h
    .F(0) = P1 * Cos(P_angle_h)
    .ma(0) = (temp_s(2).y - 2 / 3 * (temp_s(2).y - temp_s(1).y)) - temp_b(0).y
```

```
                'P1v
                .F(3) = P1 * Sin(P_angle_h)
                .ma(3) = temp_b(1).x - temp_b(0).x
                'P2h
                .F(1) = P2 * Cos(P_angle_h)
                .ma(1) = Abs(f_trap_centr_d_from_b((q_surch + gdry * (temp_s(2).y - temp_s(1).y) + gsub *
(El_gwt - temp_b(1).y)) * Ka, (q_surch + gdry * (temp_s(2).y - temp_s(1).y)) * Ka, El_gwt - temp_b(1).y))
                'P2v
                .F(4) = P2 * Sin(P_angle_h)
                .ma(4) = temp_b(1).x - temp_b(0).x
            End If
            For i = 0 To .M.GetUpperBound(0)
                .M(i) = .F(i) * .ma(i)
            Next
            'overturning
            .EMo = .M(0) + .M(1) + .M(2) + .M(8)
            .EMr = .M(3) + .M(4) + .M(5) + .M(6) + .M(7)
            .FSo = .EMr / .EMo
            If .FSo >= Fso_sw Then
                .OK_o = True
            Else
                .OK_o = False
            End If
            'sliding
            Ftot_h = .F(0) + .F(1) + .F(2)
            Ftot_v = .F(3) + .F(4) + .F(5) + .F(6) + .F(7) - .F(8)
            FSs_comp = f * Ftot_v / Ftot_h
            If FSs_comp > FSs_sw Then
                OK_s = True
            Else
                OK_s = False
            End If
        End With
    End Sub
    Private Sub compute_base_pressures()
        With MVo_toe
            .B_base = Bsw
            .EV_base = Ftot_v
            .x_base = (.EMr - .EMo) / .EV_base
            .e_base = .B_base / 2 - .x_base
            .c_base = .B_base / 2
            .M_base = .EV_base * .e_base
            .I_base = .B_base ^ 3 / 12
            .A_base = .B_base * 1 'for unit width
            .Vtoe = .EV_base / .A_base + .M_base * .c_base / .I_base
            .Vheel = .EV_base / .A_base - .M_base * .c_base / .I_base
            If Max(.Vtoe, .Vheel) <= Vmax_sw Then
                .OK_vmax = True
            Else
                .OK_vmax = False
            End If
            If Min(.Vtoe, .Vheel) >= Vmin_sw Then
                .OK_vmin = True
            Else
                .OK_vmin = False
            End If
        End With
    End Sub
#End Region
#Region "Class interface"
    Private Sub compute()
```

```
Dim i As Integer
compute_sliding_overt()
compute_base_pressures()
If Me.coulomb_type = False Then '(rankine type; usually for RC cantilever type)
    'for cantilever, soil width t3 is tried to be increased for satisfactory criteria
    If Me.change_dim_type = 1 Then  'if Bw is change to satisfy stability criteria
        i = 0
        Do While (Me.satisfactory_pro = False)
            Me.t3 += 0.1 'due to my algorithm; also t3 must be increased in order to obtain my will
            Me.Bsw += 0.1 'inremented 10 cm
            compute_sliding_overt()
            compute_base_pressures()
            i += 1
            If i >= max_iter_dim Then
                Exit Do
            End If
        Loop
        If i > max_iter_dim Then error_iter = True
    ElseIf Me.change_dim_type = 2 Then
        Me.t3 = 0.1
        Me.Bsw = t2 + tc_base + t3
        i = 0
        Do While (Me.satisfactory_pro = False)
            Me.t3 += 0.1 'due to my algorithm; also t3 must be increased in order to obtain my will
            Me.Bsw += 0.1 'inremented 10 cm
            compute_sliding_overt()
            compute_base_pressures()
            i += 1
            If i >= max_iter_dim Then
                Exit Do
            End If
        Loop
        If i > max_iter_dim Then error_iter = True
    End If
Else   '(coulomb type; usually for gravity type)
    'for coulomb type tc_base is tried to be incresed by taking tc constant for satisfactory criteria
    If Me.change_dim_type = 1 Then  'if Bw is change to satisfy stability criteria
        i = 0
        Do While (Me.satisfactory_pro = False)
            Me.tc_base += 0.1 'due to my algorithm; also t3 must be increased in order to obtain my will
            Me.Bsw += 0.1 'inremented 10 cm
            mh_sw = (tc_base - (tc + mh_free * (Ksw - Kus))) / (Ksw - Kus)
            compute_sliding_overt()
            compute_base_pressures()
            i += 1
            If i >= max_iter_dim Then
                Exit Do
            End If
        Loop
        If i > max_iter_dim Then error_iter = True
    ElseIf Me.change_dim_type = 2 Then
        Me.tc_base = tc + mh_free * (Ksw - Kus) + 0.1
        Me.Bsw = t2 + tc_base + t3
        i = 0
        Do While (Me.satisfactory_pro = False)
            Me.tc_base += 0.1 'due to my algorithm; also t3 must be increased in order to obtain my will
            Me.Bsw += 0.1 'inremented 10 cm
            mh_sw = (tc_base - (tc + mh_free * (Ksw - Kus))) / (Ksw - Kus)
            compute_sliding_overt()
            compute_base_pressures()
            i += 1
```

```
                If i >= max_iter_dim Then
                    Exit Do
                End If
            Loop
            If i > max_iter_dim Then error_iter = True
        End If
    End If
End Sub
#End Region
#Region "Properties"

    Public ReadOnly Property inp_beta_pro() As Single
        Get
            Return beta
        End Get
    End Property
    Public ReadOnly Property inp_alfa_pro() As Single
        Get
            Return alfa
        End Get
    End Property
    Public ReadOnly Property inp_teta_pro() As Single
        Get
            Return teta
        End Get
    End Property
    Public ReadOnly Property inp_gdry_pro() As Single
        Get
            Return gdry
        End Get
    End Property
    Public ReadOnly Property inp_gsat_pro() As Single
        Get
            Return gsat
        End Get
    End Property
    Public ReadOnly Property inp_gsub_pro() As Single
        Get
            Return gsub
        End Get
    End Property
    Public ReadOnly Property inp_gw_pro() As Single
        Get
            Return gw
        End Get
    End Property
    Public ReadOnly Property inp_gconc_pro() As Single
        Get
            Return gconc
        End Get
    End Property
    Public ReadOnly Property inp_f_pro() As Single
        Get
            Return f
        End Get
    End Property
    Public ReadOnly Property inp_Kus_pro() As Single
        Get
            Return Kus
        End Get
    End Property
```

```
Public ReadOnly Property inp_y2max_pro() As Single
    Get
        Return y2max
    End Get
End Property
Public ReadOnly Property inp_tc_pro() As Single
    Get
        Return tc
    End Get
End Property
Public ReadOnly Property inp_tc_base_pro() As Single
    Get
        Return tc_base
    End Get
End Property
Public ReadOnly Property inp_El_base_pro() As Single
    Get
        Return El_base
    End Get
End Property
Public ReadOnly Property inp_t1_pro() As Single
    Get
        Return t1
    End Get
End Property
Public ReadOnly Property inp_t2_pro() As Single
    Get
        Return t2
    End Get
End Property
Public ReadOnly Property inp_t3_pro() As Single
    Get
        Return t3
    End Get
End Property
Public ReadOnly Property inp_mh_free_pro() As Single
    Get
        Return mh_free
    End Get
End Property
Public ReadOnly Property inp_El_gwt_pro() As Single
    Get
        Return El_gwt
    End Get
End Property
Public ReadOnly Property inp_fsoil_pro() As Single
    Get
        Return fsoil
    End Get
End Property
Public ReadOnly Property inp_q_surch_pro() As Single
    Get
        Return q_surch
    End Get
End Property
Public ReadOnly Property inp_coulomb_type_pro() As Boolean
    Get
        Return coulomb_type
    End Get
End Property
Public ReadOnly Property inp_Fso_sw_pro() As Single
```

```
            Get
                Return Fso_sw
            End Get
        End Property
        Public ReadOnly Property inp_FSs_sw_pro() As Single
            Get
                Return FSs_sw
            End Get
        End Property
        Public ReadOnly Property inp_Vmax_sw_pro() As Single
            Get
                Return Vmax_sw
            End Get
        End Property
        Public ReadOnly Property inp_Vmin_sw_pro() As Single
            Get
                Return Vmin_sw
            End Get
        End Property
        Public ReadOnly Property error_log_pro() As Boolean
            Get
                Return (error_iter)
            End Get
        End Property
        Public ReadOnly Property satisfactory_pro() As Boolean
            Get
                Return (Me.OK_s And Me.MVo_toe.OK_o And Me.MVo_toe.OK_vmax And
Me.MVo_toe.OK_vmin)
            End Get
        End Property
        Public ReadOnly Property Area_conc_pro() As Single
            Get
                Return (MVo_toe.F(5) / gconc)
            End Get
        End Property
        Public ReadOnly Property MVo_toe_pro() As MVo
            Get
                Return MVo_toe
            End Get
        End Property
        Public ReadOnly Property Ka_pro() As Single
            Get
                Return Ka
            End Get
        End Property
        Public ReadOnly Property P1_pro() As Single
            Get
                Return P1
            End Get
        End Property
        Public ReadOnly Property P2_pro() As Single
            Get
                Return P2
            End Get
        End Property
        Public ReadOnly Property S_pro() As Single
            Get
                Return S
            End Get
        End Property
        Public ReadOnly Property Ksw_pro() As Single
```

```
            Get
                Return Ksw
            End Get
        End Property
        Public ReadOnly Property P_angle_h_pro() As Single
            Get
                Return P_angle_h
            End Get
        End Property
        Public ReadOnly Property Ftot_h_pro() As Single
            Get
                Return Ftot_h
            End Get
        End Property
        Public ReadOnly Property Ftot_v_pro() As Single
            Get
                Return Ftot_v
            End Get
        End Property
        Public ReadOnly Property FSs_comp_pro() As Single
            Get
                Return FSs_comp
            End Get
        End Property
        Public ReadOnly Property OK_s_pro() As Single
            Get
                Return OK_s
            End Get
        End Property
        Public ReadOnly Property coulomb_type_pro() As Boolean
            Get
                Return coulomb_type
            End Get
        End Property
#End Region
#Region "Constructors"
        'note: inp_change_Bsw has three values
        '      if 0; no change is done
        '      if 1; if initial value does not satisfy then incremented
        '      if 2; Bsw is calculated by setting a small initial value (real optimization; Bsw is output)
        Public Sub New(ByVal input1 As stab_mtrl_input_data, ByVal input2 As stab_Fs_input_data, ByVal
input3 As stab_sidewall_input_data)
            change_dim_type = input3.change_dim_type
            alfa = input1.alfa
            teta = input1.teta
            gdry = input1.gdry
            gsat = input1.gsat
            gconc = input1.gconc
            gw = input1.gwater
            f = input1.f
            FSs_sw = input2.FSs_sw
            Fso_sw = input2.FSo_sw
            Vmax_sw = input2.Vmax_sw
            Vmin_sw = input2.Vmin_sw
            MVo_toe = New MVo() 'create MVo_toe class
            ReDim MVo_toe.F(8) '9 forces
            ReDim MVo_toe.M(8)
            ReDim MVo_toe.ma(8)
            With input3
                Kus = .Kus
                y2max = .y2max
```

```
            tc = .tc
            t1 = .t1
            t2 = .t2
            t3 = .t3
            tc_base = .tc_base
            mh_free = .mh_free
            El_base = .El_base
            fsoil = .fsoil
            q_surch = .q_surch
            coulomb_type = .coulomb_type
        End With
        Ksw = Kus + y2max + 0.2 * (1 + y2max) 'add freeboard also
        El_gwt = Ksw - input3.gwd
        mh_sw = (tc_base - (tc + mh_free * (Ksw - Kus))) / (Ksw - Kus)
        Bsw = t2 + tc_base + t3
        error_iter = False
        Me.compute()
    End Sub
#End Region
  End Class
#End Region
End Namespace
Namespace levees_and_diversion
#Region "Data Structures"
  <Serializable()> Public Class unit_costs_input_data
    'for diversion fac
    Public uCe As Single 'unit cost of excavation
    Public uCl As Single 'unit cost of canal lining
    Public uCex As Single 'unit cost of expropriation
    Public uCcore As Single 'unit cost of embankment core construction
    Public uCper As Single 'unit cost of embankment pervious fill constr
    Public Sub New(ByVal inp As unit_costs_input_data)
        With Me
            .uCcore = inp.uCcore
            .uCe = inp.uCe
            .uCex = inp.uCex
            .uCl = inp.uCl
            .uCper = inp.uCper
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
  <Serializable()> Public Class diversion_input_data
    Public Kta As Single
    Public Ktb As Single
    Public Kb As Single
    Public delta_s As Single 'start (try) value delta drop height at d/s diversion canal
    Public Q As Single
    Public profile_name As String 'which profile to use

    Public n As Single  ' manning
    Public Ldc As Single
    Public dx As Single  'increment dist for standart step
    Public Lt As Single 'width of the river at the construction site; can be taken as width at spillway axis
    Public mh_u As Single 'u/s cofferdam u/s slope
    Public mh_d As Single 'u/s cofferdam d/s slope
    Public mh As Single 'trap canal side slope
    Public Sub New(ByVal inp As diversion_input_data)
        With Me
            .delta_s = inp.delta_s
```

```
            .dx = inp.dx
            .Kb = inp.Kb
            .Kta = inp.Kta
            .Ktb = inp.Ktb
            .Ldc = inp.Ldc
            .Lt = inp.Lt
            .mh = inp.mh
            .mh_d = inp.mh_d
            .mh_u = inp.mh_u
            .n = inp.n
            .profile_name = inp.profile_name
            .Q = inp.Q
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
  <Serializable()> Public Class diversion_try_output_data
    Public b As Single
    Public delta As Single
    Public Kc As Single
    Public Kc_Kb As Single
    Public yc As Single
    Public ymax As Single
    Public Kcb As Single 'bottom elev of pointc
    Public Sodc As Single 'slope changes for each delta change
    Public z As Single
    Public w As Single
    Public Ct As Single
    Public Cc As Single
    Public Cuc As Single
    Public Cdc As Single
    Public Sub New(ByVal inp As diversion_try_output_data)
        With Me
            .b = inp.b
            .Cc = inp.Cc
            .Cdc = inp.Cdc
            .Ct = inp.Ct
            .Cuc = inp.Cuc

            .delta = inp.delta
            .Kc = inp.Kc
            .Kc_Kb = inp.Kc_Kb
            .Kcb = inp.Kcb
            .Sodc = inp.Sodc
            .w = inp.w
            .yc = inp.yc
            .ymax = inp.ymax
            .z = inp.z
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
#End Region
#Region "Classes"
  <Serializable()> Public Class levees
#Region "private variables"
    'inputs
    Private Kdes As Single
    Private Qdes As Single
```

```
    Private n As Single
    Private Kst As Single
    Private Lt As Single
    Private So As Single
    Private dx As Single
    Private z As Single
    'outputs
    Private wsprofile As ws_profile
    Private ynormal As Single  'normal depth
    Private f_star() As Single
    Private El_levee_crest() As Single
#End Region
#Region "Class interface"
    Private Sub compute()
      Dim y_start As Single
      Dim i As Integer
      ynormal = f_ynormal(Qdes, Lt, z, n, So)
      wsprofile = New ws_profile(Qdes, n, Lt, So, Kst, z, Kdes - Kst, ynormal, dx)
      ReDim f_star(wsprofile.xsec_pro.GetUpperBound(0))
      ReDim El_levee_crest(wsprofile.xsec_pro.GetUpperBound(0))
      For i = 0 To wsprofile.xsec_pro.GetUpperBound(0)
        f_star(i) = wsprofile.xsec_pro(i).f_pro + 2
        El_levee_crest(i) = wsprofile.xsec_pro(i).Hgl_pro + f_star(i)
      Next
    End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property inp_Kdes_pro() As Single
      Get
        Return Kdes
      End Get
    End Property
    Public ReadOnly Property inp_Qdes_pro() As Single
      Get
        Return Qdes
      End Get
    End Property
    Public ReadOnly Property inp_n_pro() As Single
      Get
        Return n
      End Get
    End Property
    Public ReadOnly Property inp_Kst_pro() As Single
      Get
        Return Kst
      End Get
    End Property
    Public ReadOnly Property inp_Lt_pro() As Single
      Get
        Return Lt
      End Get
    End Property
    Public ReadOnly Property inp_So_pro() As Single
      Get
        Return So
      End Get
    End Property
    Public ReadOnly Property inp_dx_pro() As Single
      Get
        Return dx
      End Get
```

```
        End Property
        Public ReadOnly Property inp_z_pro() As Single
            Get
                Return z
            End Get
        End Property
        '*******************************
        Public ReadOnly Property wsprofile_pro() As ws_profile
            Get
                Return wsprofile
            End Get
        End Property
        Public ReadOnly Property ynormal_pro() As Single
            Get
                Return ynormal
            End Get
        End Property
        Public ReadOnly Property f_star_pro() As Single()
            Get
                Return f_star
            End Get
        End Property
        Public ReadOnly Property El_levee_crest_pro() As Single()
            Get
                Return El_levee_crest
            End Get
        End Property
#End Region
#Region "Constructors"
        Public Sub New(ByVal inp_Kdes, ByVal inp_Kst, ByVal inp_Lt, ByVal inp_z, ByVal inp_Qdes, ByVal
inp_So, ByVal inp_n, ByVal inp_dx)
            Qdes = inp_Qdes
            Kdes = inp_Kdes
            Kst = inp_Kst
            Lt = inp_Lt
            z = inp_z
            So = inp_So
            dx = inp_dx
            n = inp_n
            Me.compute()
        End Sub
#End Region
    End Class
    <Serializable()> Public Class diversion_fac
        Public Shared max_iter_delta As Integer = 100
        Public Shared max_iter_Bdiv As Integer = 100
        Public Shared inc_b = 0.25
#Region "Private variables"
        'inputs
        Private input_div As diversion_input_data
        Private input_uC As unit_costs_input_data  'unit costs
        'outputs
        Private wsprofile(0) As ws_profile 'firstly 1 calc (initial calc) water surface profile calculations
        Private div_try(0) As diversion_try_output_data  'diversion data for each try
        Private index_opt As Integer  'optimum value's index in the arrays
        Private error_log As Boolean
        'same for u/s and d/s cofferdams, only for d/s cofferdam w is used instead of w
        Public Shared Function f_Ccoffers(ByVal inp_z As Single, ByVal inp_mh_u As Single, ByVal
inp_mh_d As Single, ByVal inp_Ccore As Single, ByVal inp_Cper As Single, ByVal inp_Lt As Single) As
Single
```

```
        Return (inp_Ccore * (3 + inp_z) * inp_z / 2 + (((inp_mh_u + inp_mh_d) * inp_z + 2 * (inp_z / 5 + 3))
* inp_z / 2 - (3 + inp_z) * inp_z / 2) * inp_Cper) * inp_Lt
    End Function
    Public Shared Function f_Cc(ByVal inp_b As Single, ByVal inp_z As Single, ByVal inp_uCe As Single,
ByVal inp_uCl As Single, ByVal inp_uCex As Single, ByVal inp_Ldc As Single) As Single
        Return ((inp_b * inp_z + 1.5 * inp_z ^ 2) * inp_uCe + (inp_b + 3.61 * inp_z) * inp_uCl + (inp_b + 3 *
inp_z + 10) * inp_uCex) * inp_Ldc
    End Function
    Private Sub check_Ks_Kb(ByVal inp_i As Integer)
        Dim i As Integer = 0
        With div_try(inp_i)
            'initial check (check of the  delta start value)
            .delta = input_div.delta_s
            .yc = f_ycritical(input_div.Q, .b, input_div.mh)
            .Kc = input_div.Ktb + .yc + .delta
            .Kc_Kb = .Kc - input_div.Kb
            'if initial not satisfied incement delta
            While (.Kc_Kb < 0.3) And i <= max_iter_delta 'Kc-Kb>=0.3 meter
                .delta += 0.1  'increment for delta was taken as 10 cm
                .yc = f_ycritical(input_div.Q, .b, input_div.mh)
                .Kc = input_div.Ktb + .yc + .delta
                .Kc_Kb = .Kc - input_div.Kb
                i += 1
            End While
            .Kcb = input_div.Ktb + .delta
            .Sodc = (input_div.Kta - .Kcb) / input_div.Ldc
        End With
    End Sub
    Private Sub compute_cost(ByVal inp_i As Integer)
        With div_try(inp_i)
            .Cc = Me.f_Cc(.b, .z, input_uC.uCe, input_uC.uCl, input_uC.uCex, input_div.Ldc)
            .Cdc = Me.f_Ccoffers(.z, input_div.mh_u, input_div.mh_d, input_uC.uCcore, input_uC.uCper,
input_div.Lt)
            .Cuc = Me.f_Ccoffers(.w, input_div.mh_u, input_div.mh_d, input_uC.uCcore, input_uC.uCper,
input_div.Lt)
            .Ct = .Cuc + .Cdc + .Cc
        End With
    End Sub
    Private Sub compute_ymax_z_w(ByVal inp_i)
        With div_try(inp_i)
            .ymax = wsprofile(inp_i).y_end_comp_pro
            .z = .ymax + 0.2 * (1 + .ymax)
            .w = .z - 0.5
        End With
    End Sub
#End Region
#Region "Class interface"
    Private Sub compute()
        Dim i As Integer = 0
        Dim j As Integer
        With input_div
            'initial try
            div_try(0) = New diversion_try_output_data()
            div_try(0).b = inc_b '0.25 start try value
            Me.check_Ks_Kb(0)
            wsprofile(0) = New ws_profile(.Q, .n, div_try(0).b, div_try(0).Sodc, div_try(0).Kcb, .mh,
div_try(0).yc, .Ldc, .dx, True)
            Me.compute_ymax_z_w(0)
            Me.compute_cost(0)
            Do
                i += 1
```

```
                If i >= max_iter_Bdiv Then
                    Exit Do
                End If
                ReDim Preserve wsprofile(wsprofile.GetUpperBound(0) + 1)
                ReDim Preserve div_try(div_try.GetUpperBound(0) + 1)
                div_try(i) = New diversion_try_output_data()
                div_try(i).b = div_try(i - 1).b + inc_b 'increment 0.25
                Me.check_Ks_Kb(i)
                wsprofile(i) = New ws_profile(.Q, .n, div_try(i).b, div_try(0).Sodc, div_try(0).Kcb, .mh, 1.001 *
div_try(i).yc, .Ldc, .dx, True)
                Me.compute_ymax_z_w(i)
                Me.compute_cost(i)
                'Debug.WriteLine(div_try(i).b & " " & div_try(i).Cuc & " " & div_try(i).Cdc & " " &
div_try(i).Cc & " " & div_try(i).Ct)
            Loop While (div_try(i - 1).Ct >= div_try(i).Ct)  'if i greater than 100, means above 100 iterations,
there is a problem and quit
            index_opt = i - 1
            If (index_opt = 100) Then
                error_log = True 'means that an optimal solution curve can't be reached (iteration not enough)
            Else
                error_log = False
                'in order to see a good curve; some extra data generated beyond the optimum value
                For j = i + 1 To i + 30
                    ReDim Preserve wsprofile(wsprofile.GetUpperBound(0) + 1)
                    ReDim Preserve div_try(div_try.GetUpperBound(0) + 1)
                    div_try(j) = New diversion_try_output_data()
                    div_try(j).b = div_try(j - 1).b + inc_b 'increment 0.25
                    Me.check_Ks_Kb(j)
                    wsprofile(j) = New ws_profile(.Q, .n, div_try(j).b, div_try(j).Sodc, div_try(j).Kcb, .mh, 1.001 *
div_try(j).yc, .Ldc, .dx, True)
                    Me.compute_ymax_z_w(j)
                    Me.compute_cost(j)
                Next
            End If
        End With
    End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property input_div_pro() As diversion_input_data
        Get
            Return input_div
        End Get
    End Property
    Public ReadOnly Property input_uC_pro() As unit_costs_input_data
        Get
            Return input_uC
        End Get
    End Property

    Public ReadOnly Property wsprofile_pro() As ws_profile()
        Get
            Return wsprofile
        End Get
    End Property
    Public ReadOnly Property div_try_pro() As diversion_try_output_data()
        Get

            Return div_try
        End Get
    End Property
    Public ReadOnly Property opt_values_pro() As diversion_try_output_data
```

```
            Get
                Return div_try(index_opt)
            End Get
        End Property
        Public ReadOnly Property opt_wsprofile_pro() As ws_profile
            Get
                Return wsprofile(index_opt)
            End Get
        End Property
        Public ReadOnly Property error_log_pro() As Boolean
            Get
                Return error_log
            End Get
        End Property
#End Region
#Region "Constructors"
        Public Sub New(ByVal input1 As diversion_input_data, ByVal input2 As unit_costs_input_data)
            Me.input_div = input1
            Me.input_uC = input2
            Me.compute()
        End Sub
#End Region
    End Class
#End Region
End Namespace
Namespace cost_computations
#Region "Data structures"
    <Serializable()> Public Class costs_input_data
        'pointer to the calculated classes
        Public int_hyd As intake_design.intake  'intake hydraulic
        Public int_geom As stability_analysis.stab_uplift_sb   'intake
        Public splw_geom As stability_analysis.stab_uplift_sb  'spillway
        Public slcw_geom As stability_analysis.stab_uplift_sb  'sluiceway
        Public Q_splw_slcw As splw_slcw_design.splw_slcw_Q
        Public energy_dissp As splw_slcw_design.energy_dissp
        Public sidewalls_splw_geom As stability_analysis.stab_sidewalls  'sidewalls
        Public sidewalls_slcw_geom As stability_analysis.stab_sidewalls  'sidewalls
        Public slide_overt As stability_analysis.stab_sliding_and_overt
        Public riprap_geom As Appurtenant_fac.riprap_des       'riprap
        Public flush_geom As Appurtenant_fac.flushing_canal    'flushing canal
        Public divfac_geom As levees_and_diversion.diversion_fac  'diversion facility
        'levees to be added
        'new inputs...........(input as directly to the class)
        'unit cost values
        Public uC_conc As Single
        Public uC_riprap As Single
        Public uC_steel As Single
        Public tslab As Single 'some additional data for trap/rect canal dimensions
        Public twall As Single 'some additional data for trap/rect canal dimensions
        Public Lp, Lp2, tg, tg2, t_blanket, t_sheet, width_tr As Single 'pier lengths and gate thicknesses ;
width_tr: width of rackbars
        Public Lp_slcw, tg_slcw As Single  'slcw pier length and gate thickness
        Public Lp_bridge, tslab_bridge, width_bridge As Single  'brigge over splw,slcw and intake if exists
        Public Sub New(ByVal inp As costs_input_data)
            With Me
                .divfac_geom = inp.divfac_geom
                .energy_dissp = inp.energy_dissp
                .flush_geom = inp.flush_geom
                .int_geom = inp.int_geom
                .int_hyd = inp.int_hyd
                .Lp = inp.Lp
```

```
            .Lp2 = inp.Lp2
            .Lp_bridge = inp.Lp_bridge
            .Lp_slcw = inp.Lp_slcw
            .Q_splw_slcw = inp.Q_splw_slcw
            .riprap_geom = inp.riprap_geom
            .sidewalls_slcw_geom = inp.sidewalls_slcw_geom
            .sidewalls_splw_geom = inp.sidewalls_splw_geom
            .slcw_geom = inp.slcw_geom
            .slide_overt = inp.slide_overt
            .splw_geom = inp.splw_geom
            .t_blanket = inp.t_blanket
            .t_sheet = inp.t_sheet
            .tg = inp.tg
            .tg2 = inp.tg2
            .tg_slcw = inp.tg_slcw
            .tslab = inp.tslab
            .tslab_bridge = inp.tslab_bridge
            .twall = inp.twall
            .uC_conc = inp.uC_conc
            .uC_riprap = inp.uC_riprap
            .uC_steel = inp.uC_steel
            .width_bridge = inp.width_bridge
            .width_tr = inp.width_tr
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
#End Region
#Region "Classes"
  <Serializable()> Public Class costs
    Const gsteel = 7800 'kgf/m3
    Const steel_conc_ratio = 80 'kgf/m3 :for 1 m3 concrete 80 kg steel exists approximately
#Region "Private variables"
    'inputs**********************************************************************************
    'pointer to the calculated classes
    Private int_hyd As intake_design.intake  'intake hydraulic
    Private int_geom As stability_analysis.stab_uplift_sb   'intake
    Private splw_geom As stability_analysis.stab_uplift_sb  'spillway
    Private slcw_geom As stability_analysis.stab_uplift_sb  'sluiceway
    Private Q_splw_slcw As splw_slcw_design.splw_slcw_Q
    Private energy_dissp As splw_slcw_design.energy_dissp
    Private sidewalls_splw_geom As stability_analysis.stab_sidewalls  'sidewalls
    Private sidewalls_slcw_geom As stability_analysis.stab_sidewalls  'sidewalls
    Private slide_overt As stability_analysis.stab_sliding_and_overt
    Private riprap_geom As Appurtenant_fac.riprap_des       'riprap
    Private flush_geom As Appurtenant_fac.flushing_canal    'flushing canal
    Private divfac_geom As levees_and_diversion.diversion_fac  'diversion facility
    'levees to be added
    'new inputs...........(input as directly to the class)
    'unit cost values
    Private uC_conc As Single
    Private uC_riprap As Single
    Private uC_steel As Single
    Private tslab As Single 'some additional data for trap/rect canal dimensions
    Private twall As Single 'some additional data for trap/rect canal dimensions
    Private Lp, Lp2, tg, tg2, t_blanket, t_sheet, width_tr As Single 'pier lengths and gate thicknesses ;
width_tr: width of rackbars
    Private Lp_slcw, tg_slcw As Single  'slcw pier length and gate thickness
    Private Lp_bridge, tslab_bridge, width_bridge As Single  'brigge over splw,slcw and intake if exists
    'outputs**********************************************************************************
```

```
'intake
Private vol_slab_int As Single   'bottom foundation concrete
Private vol_sides_int As Single
Private vol_piers_int
Private vol_us_blanket_int As Single
Private vol_us_sheetp_int As Single
Private wgh_rackbars_int As Single
Private wgh_gates_int As Single   'weight of gates
'spillway
Private vol_slab_splw As Single
Private vol_body_splw As Single
Private vol_chute_blocks_splw As Single
Private vol_baffle_piers_splw As Single
Private vol_us_blanket_splw As Single
Private vol_us_sheetp_splw As Single
Private vol_sidewall_splw As Single
'sluiceway
Private vol_slab_slcw As Single
Private vol_body_slcw As Single
Private vol_chute_blocks_slcw As Single
Private vol_baffle_piers_slcw As Single
Private vol_us_blanket_slcw As Single
Private vol_us_sheetp_slcw As Single
Private vol_sidewall_slcw As Single
Private vol_piers_slcw As Single   'midwall for slcw gates
Private vol_guiding_wall As Single  'wall between splw and slcw (if seperate energy dissp exist this wall
extends to the end of stillbas)
Private wgh_gates_slcw As Single
'appert fac
Private vol_riprap As Single
Private vol_flush As Single
'bridge
Private vol_brigde_piers As Single  'if bridge exist over spillway
Private vol_bridge_slab As Single   'if bridge exist over spillway
'diversion fac
Private cost_canal As Single
Private cost_uscdam As Single
Private cost_dscdam As Single
Private cost_div_fac As Single
Private Sub compute_intake()
    Dim i As Integer
    vol_slab_int = 0
    vol_sides_int = 0
    With int_hyd
        'initialization
        .xsec_pro(0).tslab_p = tslab
        .xsec_pro(0).twall_p = twall
        'slab volume
        For i = 1 To 3
            .xsec_pro(i).tslab_p = tslab
            vol_slab_int += (.xsec_pro(i).Aconc_slab_pro + .xsec_pro(i - 1).Aconc_slab_pro) / 2 *
Abs(.xsec_pro(i).km_xsec_p - .xsec_pro(i - 1).km_xsec_p)
        Next
        vol_slab_int += int_geom.Area_slab_tot_pro * .xsec_pro(7).B_pro
        vol_slab_int += (Abs(.xsec_pro(7).km_xsec_p - .xsec_pro(6).km_xsec_p) +
Abs(.xsec_pro(7).km_xsec_p - .xsec_pro(5).km_xsec_p)) / 2 * .dsd_p * .xsec_pro(7).B_pro
        'sides volume
        For i = 1 To 7
            .xsec_pro(i).twall_p = twall
            vol_sides_int += (.xsec_pro(i).Aconc_sides_pro + .xsec_pro(i - 1).Aconc_sides_pro) / 2 *
Abs(.xsec_pro(i).km_xsec_p - .xsec_pro(i - 1).km_xsec_p)
```

```
            Next
            'rackbars volume
            wgh_rackbars_int = (.Ag_pro - .An_pro) * width_tr * gsteel
            'piers
            vol_piers_int = (.xsec_pro(1).z_pro + .xsec_pro(2).z_pro) / 2 * .tp_pro * .np_pro * Lp
            vol_piers_int += (.xsec_pro(6).z_pro + .xsec_pro(7).z_pro) / 2 * .tp_pro * .np_pro * Lp2
            'gates
            wgh_gates_int = (.xsec_pro(1).z_pro + .xsec_pro(2).z_pro) / 2 * tg * .B2n_pro * gsteel
            wgh_gates_int += (.xsec_pro(6).z_pro + .xsec_pro(7).z_pro) / 2 * tg2 * .Bsn_pro * gsteel
            'us_blanket and sheetpile
            vol_us_blanket_int = int_geom.L_blankets_pro * .xsec_pro(8).B_pro * t_blanket
            vol_us_sheetp_int = int_geom.L_sheetpile_pro * .xsec_pro(8).B_pro * t_sheet
        End With
    End Sub
    Private Sub compute_splw()
        With slcw_geom
            vol_slab_splw = .Area_slab_tot_pro * Me.Q_splw_slcw.Ls_pro
            vol_body_splw = Me.slide_overt.Area_conc_splw_pro * Me.Q_splw_slcw.Ls_pro
            With Me.energy_dissp
                vol_chute_blocks_splw = .resultsb_s_pro.vol_chute_blocks
                vol_baffle_piers_splw = .resultsb_s_pro.vol_baffle_piers
            End With
            'us_blanket and sheetpile
            vol_us_blanket_splw = splw_geom.L_blankets_pro * Me.Q_splw_slcw.Ls_pro * t_blanket
            vol_us_sheetp_splw = splw_geom.L_sheetpile_pro * Me.Q_splw_slcw.Ls_pro * t_sheet
        End With
    End Sub
    Private Sub compute_slcw()
        With slcw_geom
            'this seperation computation is made here because; spillway length is assumed to be excluding the
midwall whenever seperate or common stillbas exists
            If (Me.energy_dissp.sb_common_pro = False) Then 'seperate energy dissp
                vol_slab_slcw = .Area_slab_tot_pro * Me.Q_splw_slcw.Lsl_pro
                vol_body_slcw = (.L1_pro + .Lcutoff_tot_pro) / 2 * (int_hyd.xsec_pro(8).Kb_pro - .Elsb_us_pro)
* Me.Q_splw_slcw.Lsl_pro 'Kst is taken from intake last section bottom el
            Else   'common energy dissip; meaning that midwall filled with sluiceway stillbas
                vol_slab_slcw = .Area_slab_tot_pro * (Me.Q_splw_slcw.Lsl_pro + Me.Q_splw_slcw.tsl_pro)
                vol_body_slcw = (.L1_pro + .Lcutoff_tot_pro) / 2 * (int_hyd.xsec_pro(8).Kb_pro - .Elsb_us_pro)
* (Me.Q_splw_slcw.Lsl_pro + Me.Q_splw_slcw.tsl_pro) 'Kst is taken from intake last section bottom el
            End If
            With Me.energy_dissp
                vol_chute_blocks_slcw = .resultsb_sl_pro.vol_chute_blocks
                vol_baffle_piers_slcw = .resultsb_sl_pro.vol_baffle_piers
            End With
            'us_blanket and sheetpile
            vol_us_blanket_slcw = slcw_geom.L_blankets_pro * Me.Q_splw_slcw.Lsl_pro * t_blanket
            vol_us_sheetp_slcw = slcw_geom.L_sheetpile_pro * Me.Q_splw_slcw.Lsl_pro * t_sheet
            'piers
            vol_piers_slcw = (Q_splw_slcw.Ksl_pro - int_hyd.xsec_pro(8).Kb_pro) * Me.Q_splw_slcw.tsl_pro
* Lp_slcw * (Q_splw_slcw.nsl_pro - 1)
            'gates
            wgh_gates_slcw = (Q_splw_slcw.Ksl_pro - int_hyd.xsec_pro(8).Kb_pro) *
Me.Q_splw_slcw.Le_pro * tg_slcw * Me.Q_splw_slcw.nsl_pro * gsteel
        End With
    End Sub
    Private Sub compute_sidewalls()
        'sidewalls-splw
        vol_sidewall_splw = Me.sidewalls_splw_geom.Area_conc_pro * Me.energy_dissp.Lsb_pro
        'sidewalls-slcw
        vol_sidewall_slcw = Me.sidewalls_slcw_geom.Area_conc_pro * Me.energy_dissp.Lsb_pro
    End Sub
```

```
    Private Sub compute_guiding_wall()
      Dim El_base_splw, El_base_slcw As Single 'for temp var to compute Hmidwall if seperate dissp bas
exists
      With Me.splw_geom.geom_for_so_pro
        El_base_splw = .creep_path(.sb_end).y
      End With
      With Me.slcw_geom.geom_for_so_pro
        El_base_slcw = .creep_path(.sb_end).y
      End With
      'in all cases common guiding wall until entrance of stilling bas will exist
      With slcw_geom
        'guiding wall (may need to recompute; not exactly true)
        vol_guiding_wall = (.L_blankets_pro + .Lcutoff_tot_pro) * Me.Q_splw_slcw.tsl_pro *
(Q_splw_slcw.Ksl_pro - int_hyd.xsec_pro(8).Kb_pro)
      End With
      'extension of guidewall(midwall) computed as thickness*Lstillbas*H
      'H=spillway ve sluceway sidewalllarin crest elev larinin max olani - spillway ve sluiceway stillbas
bottom elevnin min olani
      'bylece H en safe durum olmus olur.
      'Note: midwall 'in toprak alti (foundation) kismi ihmal edilmistir.
      With Me.energy_dissp
        If .sb_common_pro = False Then  'seperate stillbas; guiding wall extends to the end of stillbasins
          vol_guiding_wall += (Max(Me.sidewalls_splw_geom.Ksw_pro,
Me.sidewalls_slcw_geom.Ksw_pro) - Min(El_base_splw, El_base_slcw)) * Me.Q_splw_slcw.tsl_pro *
.Lsb_pro
        End If
      End With
    End Sub
    Private Sub compute_riprap()
      vol_riprap = Me.riprap_geom.Vriprap_pro
    End Sub
    Private Sub compute_flush()
      Dim t As Single = Me.flush_geom.Dp_pro / 10 + 0.005 ' et kalinligi, capin 10 sa birinin 5 mm fazlasi
olarak alinmistir.
      Me.vol_flush = Me.flush_geom.Lflush_pro * PI * (Me.flush_geom.Dp_pro * t + t ^ 2)
    End Sub
    Private Sub compute_bridge()
      With Me.Q_splw_slcw
        vol_brigde_piers = .np_pro * .tp_pro * Lp_bridge * (.Ksl_pro - int_hyd.Ks_pro)
        vol_bridge_slab = (.Lt_pro + int_hyd.xsec_pro(8).B_pro) * width_bridge * tslab_bridge
      End With
    End Sub
    Private Sub compute_diversion()
      With Me.divfac_geom
        cost_canal = .opt_values_pro.Cc
        cost_uscdam = .opt_values_pro.Cuc
        cost_dscdam = .opt_values_pro.Cdc
        cost_div_fac = .opt_values_pro.Ct
      End With
    End Sub
#End Region
#Region "Class interface"
    Public Sub compute()
      Me.compute_intake()
      Me.compute_splw()
      Me.compute_slcw()
      Me.compute_sidewalls()
      Me.compute_guiding_wall()
      Me.compute_riprap()
      Me.compute_flush()
      Me.compute_bridge()
```

```
            Me.compute_diversion()
        End Sub
#End Region
#Region "Properties"
        'intake******************************************
        Public ReadOnly Property vol_conc_int_pro() As Single
            Get
                With Me
                    Return .vol_us_blanket_int + .vol_us_sheetp_int + .vol_piers_int + .vol_sides_int + .vol_slab_int
                End With
            End Get
        End Property
        Public ReadOnly Property wgh_rackbars_int_pro() As Single
            Get
                With Me
                    Return wgh_rackbars_int
                End With
            End Get
        End Property
        Public ReadOnly Property wgh_gates_int_pro() As Single
            Get
                With Me
                    Return wgh_gates_int
                End With
            End Get
        End Property
        Public ReadOnly Property wgh_steel_int_pro() As Single
            Get
                With Me
                    Return wgh_gates_int + wgh_rackbars_int
                End With
            End Get
        End Property
        Public ReadOnly Property cost_steel_int_pro() As Single
            Get
                With Me
                    Return wgh_steel_int_pro * .uC_steel
                End With
            End Get
        End Property
        Public ReadOnly Property cost_conc_int_pro() As Single
            Get
                With Me
                    Return vol_conc_int_pro * .uC_conc
                End With
            End Get
        End Property
        Public ReadOnly Property cost_tot_int_pro() As Single
            Get
                With Me
                    Return cost_conc_int_pro + cost_steel_int_pro
                End With
            End Get
        End Property
        'splw*****************************************************
        Public ReadOnly Property vol_conc_splw_pro() As Single
            Get
                With Me
                    Return .vol_us_blanket_splw + .vol_us_sheetp_splw + .vol_body_splw + .vol_slab_splw +
.vol_baffle_piers_splw + .vol_chute_blocks_splw
                End With
```

```
            End Get
        End Property
        Public ReadOnly Property cost_conc_splw_pro() As Single
            Get
                With Me
                    Return vol_conc_splw_pro * .uC_conc
                End With
            End Get
        End Property
        Public ReadOnly Property cost_tot_splw_pro() As Single
            Get
                With Me
                    Return cost_conc_splw_pro
                End With
            End Get
        End Property
        'slcw****************************************************
        Public ReadOnly Property vol_conc_slcw_pro() As Single
            Get
                With Me
                    Return .vol_us_blanket_slcw + .vol_us_sheetp_slcw + .vol_body_slcw + .vol_slab_slcw +
.vol_piers_slcw + .vol_baffle_piers_slcw + .vol_chute_blocks_slcw
                End With
            End Get
        End Property
        Public ReadOnly Property wgh_gates_slcw_pro() As Single
            Get
                With Me
                    Return wgh_gates_slcw
                End With
            End Get
        End Property
        Public ReadOnly Property wgh_steel_slcw_pro() As Single
            Get
                With Me
                    Return wgh_gates_slcw
                End With
            End Get
        End Property
        Public ReadOnly Property cost_steel_slcw_pro() As Single
            Get
                With Me
                    Return wgh_steel_slcw_pro * .uC_steel
                End With
            End Get
        End Property
        Public ReadOnly Property cost_conc_slcw_pro() As Single
            Get
                With Me
                    Return vol_conc_slcw_pro * .uC_conc
                End With
            End Get
        End Property
        Public ReadOnly Property cost_tot_slcw_pro() As Single
            Get
                With Me
                    Return cost_conc_slcw_pro + cost_steel_slcw_pro
                End With
            End Get
        End Property
        'guiding wall
```

```
Public ReadOnly Property vol_guiding_wall_pro() As Single
    Get
        With Me
            Return vol_guiding_wall
        End With
    End Get
End Property
Public ReadOnly Property cost_guiding_wall_pro() As Single
    Get
        With Me
            Return vol_guiding_wall_pro * .uC_conc
        End With
    End Get
End Property
'sidewalls
Public ReadOnly Property vol_sidewall_splw_pro() As Single
    Get
        With Me
            Return .vol_sidewall_splw
        End With
    End Get
End Property
Public ReadOnly Property wgh_steel_sidewall_splw_pro() As Single
    Get
        With Me
            Return .vol_sidewall_splw * steel_conc_ratio
        End With
    End Get
End Property
Public ReadOnly Property vol_sidewall_slcw_pro() As Single
    Get
        With Me
            Return .vol_sidewall_slcw
        End With
    End Get
End Property
Public ReadOnly Property wgh_steel_sidewall_slcw_pro() As Single
    Get
        With Me
            Return .vol_sidewall_slcw * steel_conc_ratio
        End With
    End Get
End Property
Public ReadOnly Property vol_conc_sidewall_tot_pro() As Single
    Get
        With Me
            Return .vol_sidewall_slcw + .vol_sidewall_splw
        End With
    End Get
End Property
Public ReadOnly Property wgh_steel_sidewall_tot_pro() As Single
    Get
        With Me
            Return .wgh_steel_sidewall_slcw_pro + .wgh_steel_sidewall_splw_pro
        End With
    End Get
End Property
Public ReadOnly Property cost_sidewall_tot_pro() As Single
    Get
        With Me
            'reinforced concrete steel unit cost=1/10*(steel gate unit cost)
```

```
            Return .wgh_steel_sidewall_tot_pro * .uC_steel / 10 + .vol_conc_sidewall_tot_pro * .uC_conc
        End With
    End Get
End Property
'riprap
Public ReadOnly Property vol_riprap_pro() As Single
    Get
        With Me
            Return vol_riprap
        End With
    End Get
End Property
Public ReadOnly Property cost_riprap_pro() As Single
    Get
        With Me
            Return vol_riprap_pro * .uC_riprap
        End With
    End Get
End Property
'flushing canal
Public ReadOnly Property vol_flush_pro() As Single
    Get
        With Me
            Return .vol_flush
        End With
    End Get
End Property
Public ReadOnly Property cost_flush_pro() As Single
    Get
        With Me
            Return vol_flush_pro * .uC_conc
        End With
    End Get
End Property
'bridge
Public ReadOnly Property vol_conc_bridge_pro() As Single
    Get
        With Me
            Return .vol_bridge_slab + .vol_brigde_piers
        End With
    End Get
End Property
Public ReadOnly Property wgh_steel_bridge_pro() As Single
    Get
        With Me
            Return .vol_conc_bridge_pro * steel_conc_ratio
        End With
    End Get
End Property
Public ReadOnly Property cost_bridge_pro() As Single
    Get
        With Me
            'for reinf conc steel ucost 1/10 of gates...
            Return vol_conc_bridge_pro * .uC_conc + wgh_steel_bridge_pro * .uC_steel / 10
        End With
    End Get
End Property
'diversion fac
Public ReadOnly Property cost_canal_div_pro() As Single
    Get
        With Me
```

```
                Return .cost_canal
            End With
        End Get
    End Property
    Public ReadOnly Property cost_dscdam_div_pro() As Single
        Get
            With Me
                Return .cost_dscdam
            End With
        End Get
    End Property
    Public ReadOnly Property cost_uscdam_div_pro() As Single
        Get
            With Me
                Return .cost_uscdam
            End With
        End Get
    End Property
    Public ReadOnly Property cost_tot_div_pro() As Single
        Get
            With Me
                Return .cost_div_fac
            End With
        End Get
    End Property
    '*************************************************************
    'total cost of diversion weir
    Public ReadOnly Property cost_tot_dweir_pro() As Single
        Get
            With Me
                Return .cost_bridge_pro + .cost_tot_div_pro + .cost_tot_int_pro + .cost_tot_slcw_pro +
.cost_tot_splw_pro + .cost_riprap_pro + .cost_flush_pro + .cost_guiding_wall_pro + .cost_sidewall_tot_pro
            End With
        End Get
    End Property
#End Region
#Region "Constructors"
    Public Sub New(ByVal input1 As costs_input_data)
        With input1
            Me.divfac_geom = .divfac_geom
            Me.energy_dissp = .energy_dissp
            Me.flush_geom = .flush_geom
            Me.int_geom = .int_geom
            Me.int_hyd = .int_hyd
            Me.Lp = .Lp
            Me.Lp2 = .Lp2
            Me.Lp_bridge = .Lp_bridge
            Me.Lp_slcw = .Lp_slcw
            Me.Q_splw_slcw = .Q_splw_slcw
            Me.riprap_geom = .riprap_geom
            Me.sidewalls_slcw_geom = .sidewalls_slcw_geom
            Me.sidewalls_splw_geom = .sidewalls_splw_geom
            Me.slcw_geom = .slcw_geom
            Me.slide_overt = .slide_overt
            Me.splw_geom = .splw_geom
            Me.t_blanket = .t_blanket
            Me.t_sheet = .t_sheet
            Me.tg = .tg
            Me.tg2 = .tg2
            Me.tg_slcw = .tg_slcw
            Me.tslab = .tslab
```

```
            Me.tslab_bridge = .tslab_bridge
            Me.twall = .twall
            Me.uC_conc = .uC_conc
            Me.uC_riprap = .uC_riprap
            Me.uC_steel = .uC_steel
            Me.width_bridge = .width_bridge
            Me.width_tr = .width_tr
        End With
        Me.compute()
    End Sub

#End Region
  End Class
#End Region
End Namespace
Namespace computations
#Region "Data structures"
  <Serializable()> Public Class objects_state
    Public st_intake_des As Boolean
    Public st_splw_Q As Boolean
    Public st_energy_dissp As Boolean
    Public st_riprap_des As Boolean
    Public st_flush_des As Boolean
    Public st_seepage_des As Boolean
    Public st_int_uplift As Boolean
    Public st_splw_uplift As Boolean
    Public st_slcw_uplift As Boolean
    Public st_stab_slide_overt As Boolean
    Public st_stab_sw_splw As Boolean
    Public st_stab_sw_slcw As Boolean
    Public st_levees_des As Boolean
    Public st_div_fac As Boolean
    Public st_costs As Boolean
    Public st_summary_result As Boolean
    Public st_try_summary_results As Boolean
    Public st_try_summary_results_OK As Boolean
    Public Sub New(ByVal inp As objects_state)
        With Me
            .st_costs = inp.st_costs
            .st_div_fac = inp.st_div_fac
            .st_energy_dissp = inp.st_energy_dissp
            .st_flush_des = inp.st_flush_des
            .st_int_uplift = inp.st_int_uplift
            .st_intake_des = inp.st_intake_des
            .st_levees_des = inp.st_levees_des
            .st_riprap_des = inp.st_riprap_des
            .st_seepage_des = inp.st_seepage_des
            .st_slcw_uplift = inp.st_slcw_uplift
            .st_splw_Q = inp.st_splw_Q
            .st_splw_uplift = inp.st_splw_uplift
            .st_stab_slide_overt = inp.st_stab_slide_overt
            .st_stab_sw_slcw = inp.st_stab_sw_slcw
            .st_stab_sw_splw = inp.st_stab_sw_splw
            .st_summary_result = inp.st_summary_result
            .st_try_summary_results = inp.st_try_summary_results
            .st_try_summary_results_OK = inp.st_try_summary_results_OK
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class
```

```
<Serializable()> Public Class project_type
    Public prj_main_module As Boolean
    Public prob_type As Byte 'gated or not
    Public comp_type As Byte 'optimize or not; for the time being; 0: normal, 1:optimize by Bmain
    Public prj_title As String
    Public prj_eng As String
    Public prj_def As String
    Public prj_date As Date
    Public Sub New(ByVal inp As project_type)
        With Me
            .comp_type = inp.comp_type
            .prj_date = inp.prj_date
            .prj_def = inp.prj_def
            .prj_eng = inp.prj_eng
            .prj_main_module = inp.prj_main_module
            .prj_title = inp.prj_title
            .prob_type = inp.prob_type
        End With
    End Sub
    Public Sub New()
    End Sub
End Class
<Serializable()> Public Class dweir_input_data
    Public input_intake As intake_input_data
    Public input_Q_splw_slcw As splw_slcw_Q_input_data
    Public input_energy_dissipators As energy_dissp_input_data
    Public C As Single 'creep constant
    Public So_river, min_riprap_height, Ld_min, n_river, dx_levees, z_levees As Single
    Public Dm_flush, Dp_flush, n_flush, ks_flush, alfa_int As Single
    Public input_geom_intake As stab_geom_input_data
    Public input_geom_splw As stab_geom_input_data
    Public input_geom_slcw As stab_geom_input_data
    Public input_mtrl As stab_mtrl_input_data
    Public input_sidewalls_splw As stab_sidewall_input_data
    Public input_sidewalls_slcw As stab_sidewall_input_data
    Public input_Fs As stab_Fs_input_data
    Public input_uCosts As unit_costs_input_data
    Public input_diversion As diversion_input_data
    Public input_dweir_cost As costs_input_data
    Public Hsp_spl, Lub_spl, Hsp_int, Lub_int As Single
    Public El_spl() As Single
    Public L_spl() As Single
    Public El_int() As Single
    Public L_int() As Single
    Public tc_splw As Single
    Public mh_ogee As Single
    Public crest_auto As Boolean
    Public dim_int_by_El As Boolean
    Public dim_splw_by_El As Boolean
    Public Sub New(ByVal inp As dweir_input_data)
        With Me
            .alfa_int = inp.alfa_int
            .C = inp.C
            .crest_auto = inp.crest_auto
            .dim_int_by_El = inp.dim_int_by_El
            .dim_splw_by_El = inp.dim_splw_by_El
            .Dm_flush = inp.Dm_flush
            .Dp_flush = inp.Dp_flush
            .dx_levees = inp.dx_levees
            .El_int = inp.El_int.Clone
            .El_spl = inp.El_spl.Clone
```

```
            .Hsp_int = inp.Hsp_int
            .Hsp_spl = inp.Hsp_spl
            .input_diversion = inp.input_diversion
            .input_dweir_cost = inp.input_dweir_cost
            .input_energy_dissipators = inp.input_energy_dissipators
            .input_Fs = inp.input_Fs
            .input_geom_intake = inp.input_geom_intake
            .input_geom_slcw = inp.input_geom_slcw
            .input_geom_splw = inp.input_geom_splw
            .input_intake = inp.input_intake
            .input_mtrl = inp.input_mtrl
            .input_Q_splw_slcw = inp.input_Q_splw_slcw
            .input_sidewalls_slcw = inp.input_sidewalls_slcw
            .input_sidewalls_splw = inp.input_sidewalls_splw
            .input_uCosts = inp.input_uCosts
            .ks_flush = inp.ks_flush
            .L_int = inp.L_int.Clone
            .L_spl = inp.L_spl.Clone
            .Ld_min = inp.Ld_min
            .Lub_int = inp.Lub_int
            .Lub_spl = inp.Lub_spl
            .mh_ogee = inp.mh_ogee
            .min_riprap_height = inp.min_riprap_height
            .n_flush = inp.n_flush
            .n_river = inp.n_river
            .So_river = inp.So_river
            .tc_splw = inp.tc_splw
            .z_levees = inp.z_levees
        End With
    End Sub
    Public Sub New()
    End Sub
End Class
<Serializable()> Public Class optimization_try_output_data
    Public B_main As Single
    Public Qirr As Single
    Public Qdes As Single  'Q100
    Public P As Single 'spillway height
    Public tc As Single 'spillway crest thickness
    Public Lsettl As Single 'settling basin length
    Public Bs As Single 'settling basin width
    Public xsec_main As xsec_hyd
    Public xsec_int As xsec_hyd
    Public Ks As Single
    Public Qdes_splw As Single  'Qs100
    Public Qdes_slcw As Single  'Qsl100
    Public K_des As Single 'K100
    Public sb_splw As stillingbasin
    Public sb_slcw As stillingbasin
    Public common_sb As Boolean
    Public Lcr As Single 'seepage
    Public CH As Single  'seepage
    Public OK_seepage As Boolean
    Public FSu_int As Single
    Public FSu_splw As Single
    Public FSu_slcw As Single
    Public FSs As Single
    Public FSss As Single
    Public FSs_sw_splw As Single
    Public FSs_sw_slcw As Single
    Public MVoheel As MVo
```

```
Public MVoheel_eu As MVo
Public MVotoe_eu As MVo
Public MVo_sw_splw As MVo
Public MVo_sw_slcw As MVo
Public OK_uplift_int As Boolean
Public OK_uplift_splw As Boolean
Public OK_uplift_slcw As Boolean

Public OK_s As Boolean
Public OK_ss As Boolean
Public OK_s_sw_splw As Boolean
Public OK_s_sw_slcw As Boolean
Public Lx_tot As Single 'levees length
Public B_div As Single
Public riprap_Ld As Single
Public riprap_D As Single
Public riprap_nrow As Integer
Public flush_So As Single
Public flush_Dp As Single
Public flush_Lh As Single 'horizantal length
Public cost_int As Single
Public cost_splw As Single
Public cost_slcw As Single
Public cost_sidewalls As Single
Public cost_guidingwall As Single
Public cost_riprap As Single
Public cost_flush As Single
Public cost_divfac As Single
Public cost_bridge As Single
Public cost_dweir As Single
Public err_occured As Boolean
Public accepted As Boolean
Public Sub New(ByVal inp As optimization_try_output_data)
    With Me
        .B_main = inp.B_main
        .Qirr = inp.Qirr
        .Qdes = inp.Qdes
        .P = inp.P
        .tc = inp.tc
        .Lsettl = inp.Lsettl
        .Bs = inp.Bs
        .xsec_main = inp.xsec_main
        .xsec_int = inp.xsec_int
        .Ks = inp.Ks
        .Qdes_splw = inp.Qdes_splw
        .Qdes_slcw = inp.Qdes_slcw
        .K_des = inp.K_des
        .sb_splw = inp.sb_splw
        .sb_slcw = inp.sb_slcw
        .common_sb = inp.common_sb
        .Lcr = inp.Lcr
        .CH = inp.CH
        .OK_seepage = inp.OK_seepage
        .FSu_int = inp.FSu_int
        .FSu_splw = inp.FSu_splw
        .FSu_slcw = inp.FSu_slcw
        .FSs = inp.FSs
        .FSss = inp.FSss
        .FSs_sw_splw = inp.FSs_sw_splw
        .FSs_sw_slcw = inp.FSs_sw_slcw
        .MVoheel = inp.MVoheel
```

```
            .MVoheel_eu = inp.MVoheel_eu
            .MVotoe_eu = inp.MVotoe_eu
            .MVo_sw_splw = inp.MVo_sw_splw
            .MVo_sw_slcw = inp.MVo_sw_slcw
            .OK_uplift_int = inp.OK_uplift_int
            .OK_uplift_splw = inp.OK_uplift_splw
            .OK_uplift_slcw = inp.OK_uplift_slcw
            .OK_s = inp.OK_s
            .OK_ss = inp.OK_ss
            .OK_s_sw_splw = inp.OK_s_sw_splw
            .OK_s_sw_slcw = inp.OK_s_sw_slcw
            .Lx_tot = inp.Lx_tot
            .B_div = inp.B_div
            .riprap_Ld = inp.riprap_Ld
            .riprap_D = inp.riprap_D
            .riprap_nrow = inp.riprap_nrow
            .flush_So = inp.flush_So
            .flush_Dp = inp.flush_Dp
            .flush_Lh = inp.flush_Lh
            .cost_int = inp.cost_int
            .cost_splw = inp.cost_splw
            .cost_slcw = inp.cost_slcw
            .cost_sidewalls = inp.cost_sidewalls
            .cost_guidingwall = inp.cost_guidingwall
            .cost_riprap = inp.cost_riprap
            .cost_flush = inp.cost_flush
            .cost_divfac = inp.cost_divfac
            .cost_bridge = inp.cost_bridge
            .cost_dweir = inp.cost_dweir
            .err_occured = inp.err_occured
            .accepted = inp.accepted
        End With
    End Sub
    Public Sub New()
    End Sub
  End Class  'converted to class to overcome binary serialization bug; in future everything should be
converted to class
#End Region
#Region "Classes"
  'for this part computations must be made explicitely, not in constructor region
  'Ex: dim x as new whole_dweir(....)
  '      x.compute()
  <Serializable()> Public Class whole_dweir
#Region "Private variables"
    <NonSerialized()> Private lview As System.Windows.Forms.ListView
    <NonSerialized()> Private progbar As System.Windows.Forms.ProgressBar
    Private comp_inf As Queue
    'input data for objects
    Private input_intake As intake_input_data
    Private input_Q_splw_slcw As splw_slcw_Q_input_data
    Private input_energy_dissipators As energy_dissp_input_data
    Private C As Single 'creep constant
    Private So_river, min_riprap_height, Ld_min, n_river, dx_levees, z_levees As Single
    Private Dm_flush, Dp_flush, n_flush, ks_flush, alfa_int As Single
    Private input_geom_intake As stab_geom_input_data
    Private input_geom_splw As stab_geom_input_data
    Private input_geom_slcw As stab_geom_input_data
    Private input_mtrl As stab_mtrl_input_data
    Private input_sidewalls_splw As stab_sidewall_input_data
    Private input_sidewalls_slcw As stab_sidewall_input_data
    Private input_Fs As stab_Fs_input_data
```

```
        Private input_uCosts As unit_costs_input_data
        Private input_diversion As diversion_input_data
        Private input_dweir_cost As costs_input_data
        Private Hsp_spl, Lub_spl, Hsp_int, Lub_int As Single
        Private El_spl() As Single
        Private L_spl() As Single
        Private El_int() As Single
        Private L_int() As Single
        Private tc_splw As Single
        Private mh_ogee As Single
        Private crest_auto As Boolean
        Private dim_int_by_El As Boolean
        Private dim_splw_by_El As Boolean
        Private comp_summary As New optimization_try_output_data() 'for initial (if no optimization exist)
        'objects to calculate dweir
        Private intake As intake
        Private Q_splw_slcw As splw_slcw_Q
        Private energy_dissipators As energy_dissp
        Private seepage As seepage_analysis
        Private uplift_intake As stab_uplift_sb
        Private uplift_splw As stab_uplift_sb
        Private uplift_slcw As stab_uplift_sb
        Private sliding_overturning As stab_sliding_and_overt
        Private sidewalls_splw As stab_sidewalls
        Private sidewalls_slcw As stab_sidewalls
        Private us_levees As levees
        Private diversion_fac As diversion_fac
        Private riprap As riprap_des
        Private flushing_canal As flushing_canal
        Private dweir_cost As costs
        Private Function f_accepted(ByVal weir_try As optimization_try_output_data) As Boolean
            With weir_try
                If .OK_uplift_int = False Then Return False
                If .OK_uplift_splw = False Then Return False
                If .OK_uplift_slcw = False Then Return False
                If .OK_seepage = False Then Return False
                If .OK_s = False Then Return False
                If .OK_ss = False Then Return False
                If .MVoheel.OK_o = False Then Return False
                If .MVoheel.OK_vmax = False Then Return False
                If .MVoheel.OK_vmin = False Then Return False
                If .MVoheel_eu.OK_o = False Then Return False
                If .MVoheel_eu.OK_vmax = False Then Return False
                If .MVoheel_eu.OK_vmin = False Then Return False
                If .MVotoe_eu.OK_o = False Then Return False
                If .MVotoe_eu.OK_vmax = False Then Return False
                If .MVotoe_eu.OK_vmin = False Then Return False
                If .OK_s_sw_splw = False Then Return False
                If .OK_s_sw_slcw = False Then Return False
                Return True
            End With
        End Function
#End Region
#Region "Class interface"
        Private Sub compute_wo_div_fac()
            'temporary variables
            Dim i As Integer
            'intake hydraulics************************************
            intake = New intake(input_intake)
            comp_summary.Qirr = input_intake.Qi
            comp_summary.B_main = input_intake.Bop
```

```
        comp_summary.xsec_main = intake.xsec_pro(0)
        comp_summary.xsec_int = intake.xsec_pro(8)
        comp_summary.Ks = intake.Ks_pro
        comp_summary.P = intake.P_pro
        comp_summary.Lsettl = intake.Ls_p
        comp_summary.Bs = intake.Bs_p
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(15, " Intake Hydraulics
Computation completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'Spillway_sluiceway discharges**********************
        With Me.input_Q_splw_slcw
            .Ks = intake.Ks_pro
            .Kst = Me.input_intake.Kst
        End With
        Q_splw_slcw = New splw_slcw_Q(input_Q_splw_slcw)
        comp_summary.Qdes = Me.Q_splw_slcw.input_data_pro.Q(0)
        comp_summary.Qdes_splw = Me.Q_splw_slcw.Qs_pro(0)
        comp_summary.Qdes_slcw = Me.Q_splw_slcw.Qsl_pro(0)
        comp_summary.K_des = Me.Q_splw_slcw.K_pro(0)
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(20, " Spillway and
Sluiceway Discharges Computation completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'Energy dissipators*********************************************
        With Me.input_energy_dissipators
            .K = Me.Q_splw_slcw.K_pro
            .Kd = Me.input_Q_splw_slcw.Kd
            .Kr = Me.input_Q_splw_slcw.Kr
            .Kst = Me.input_intake.Kst
            .Le = Me.input_Q_splw_slcw.Le
            .Lt = Me.input_Q_splw_slcw.Lt
            .nsl = Me.input_Q_splw_slcw.nsl
            .Q = Me.input_Q_splw_slcw.Q
            .Qs = Me.Q_splw_slcw.Qs_pro
            .Qsl = Me.Q_splw_slcw.Qsl_pro
        End With
        energy_dissipators = New energy_dissp(input_energy_dissipators)
        comp_summary.sb_splw = Me.energy_dissipators.resultsb_s_pro
        comp_summary.sb_slcw = Me.energy_dissipators.resultsb_sl_pro
        comp_summary.common_sb = Me.energy_dissipators.sb_common_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25, " Energy Dissipators
Computation completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'seepage analysis*******************************************************
        Dim El_spl_temp() As Single = El_spl.Clone
        With Me.input_geom_splw
            If Me.dim_splw_by_El = False Then  'if dim are by slab thicknesses; they are converted to
elevations
                For i = 0 To 2
                    El_spl_temp(i) = Me.input_intake.Kst - Me.El_spl(i)
                Next
                For i = 3 To Me.El_spl.GetUpperBound(0)
                    El_spl_temp(i) = Me.input_energy_dissipators.Kr - Me.energy_dissipators.delta_s_pro -
Me.El_spl(i)
                Next
            End If
            ReDim .creep_path(12)
            .creep_path(0) = New c_point(0, Me.input_intake.Kst)
            .creep_path(1) = New c_point(0, .creep_path(0).y - Hsp_spl)
```

```
            .creep_path(2) = New c_point(0, .creep_path(0).y - Hsp_spl)
            .creep_path(3) = New c_point(0, .creep_path(0).y)
            .creep_path(4) = New c_point(Lub_spl, .creep_path(0).y)
            .creep_path(5) = New c_point(Lub_spl, El_spl_temp(0))
            .creep_path(6) = New c_point(.creep_path(5).x + L_spl(0), El_spl_temp(1))
            .creep_path(7) = New c_point(.creep_path(6).x + L_spl(1), El_spl_temp(2))
            .creep_path(8) = New c_point(.creep_path(7).x + L_spl(2), El_spl_temp(3))
            .creep_path(9) = New c_point(.creep_path(8).x + Me.energy_dissipators.Lsb_pro - L_spl(3),
El_spl_temp(4)) 'remember Lsb whole length to the end of sill
            .creep_path(10) = New c_point(.creep_path(9).x + L_spl(3), El_spl_temp(5))
            .creep_path(11) = New c_point(.creep_path(10).x + L_spl(4), El_spl_temp(6))
            .creep_path(12) = New c_point(.creep_path(11).x, Me.input_Q_splw_slcw.Kr)
            .delta = Me.energy_dissipators.resultsb_s_pro.delta
            .Kr = Me.input_Q_splw_slcw.Kr
            .Ks = Me.intake.Ks_pro
            .Kst = Me.input_intake.Kst
            .mh_delta = 2
            .sb_end = 9
            .sb_start = 8
            .Ssb = 0
            .str_start = 4
        End With
        seepage = New seepage_analysis(C, Me.Q_splw_slcw.K_pro, Me.input_Q_splw_slcw.Kd,
Me.intake.Ks_pro, Me.input_Q_splw_slcw.Kr, Me.input_geom_splw.creep_path,
Me.input_Q_splw_slcw.profile)
        comp_summary.Lcr = Me.seepage.Lcr_pro
        comp_summary.CH = Me.seepage.CH_pro
        comp_summary.OK_seepage = Me.seepage.satisfactory_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(30, " Seepage Analysis
completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'intake stability analysis (uplift)****************************************************
        Dim EL_int_temp() As Single = El_int.Clone
        With Me.input_geom_intake
            If Me.dim_int_by_El = False Then  'if dim are by slab thicknesses; they are converted to elevations
                For i = 0 To 2
                    EL_int_temp(i) = Me.input_intake.Kst - Me.El_int(i)
                Next
                For i = 3 To Me.El_int.GetUpperBound(0)
                    EL_int_temp(i) = Me.intake.xsec_pro(4).Kb_pro - Me.El_int(i)
                Next
            End If
            ReDim .creep_path(12)
            .creep_path(0) = New c_point(0, Me.input_intake.Kst)
            .creep_path(1) = New c_point(0, .creep_path(0).y - Hsp_int)
            .creep_path(2) = New c_point(0, .creep_path(0).y - Hsp_int)
            .creep_path(3) = New c_point(0, .creep_path(0).y)
            .creep_path(4) = New c_point(Lub_int, .creep_path(0).y)
            .creep_path(5) = New c_point(Lub_int, EL_int_temp(0))
            .creep_path(6) = New c_point(.creep_path(5).x + L_int(0), EL_int_temp(1))
            .creep_path(7) = New c_point(.creep_path(6).x + L_int(1), EL_int_temp(2))
            .creep_path(8) = New c_point(.creep_path(7).x + L_int(2), EL_int_temp(3))
            .creep_path(9) = New c_point(.creep_path(8).x + Me.intake.Ls_p, EL_int_temp(4))
            .creep_path(10) = New c_point(.creep_path(9).x + L_int(3), EL_int_temp(5))
            .creep_path(11) = New c_point(.creep_path(10).x + L_int(4), EL_int_temp(6))
            .creep_path(12) = New c_point(.creep_path(11).x, Me.intake.xsec_pro(3).Kb_pro)
            .delta = Me.intake.dsu_p  'delta is Dsu here
            .Kr = Me.intake.xsec_pro(3).Kb_pro  'for intake bottom elev at section-3 is considerd instead of Kr
            .Ks = Me.Q_splw_slcw.K_pro(0)  'for intake K100 is considered instead of Ks in spillway
            .Kst = Me.input_intake.Kst
```

```
            .mh_delta = 2
            .sb_end = 9
            .sb_start = 8
            .Ssb = Me.input_intake.Sd  'settling basin slope
            .str_start = 4
        End With
        uplift_intake = New stab_uplift_sb(False, input_geom_intake, input_mtrl.gwater, input_mtrl.gconc,
input_Fs.Fsu, input_mtrl.ured_perc)
        comp_summary.FSu_int = Me.uplift_intake.Fsu_final_pro
        comp_summary.OK_uplift_int = Me.uplift_intake.satisfactory_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(35, " Intake Stability
Analysis against Uplift completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '*****************************************************
        'spillway stab analyis (uplift)*****************************************************
        uplift_splw = New stab_uplift_sb(True, input_geom_splw, input_mtrl.gwater, input_mtrl.gconc,
input_Fs.Fsu, input_mtrl.ured_perc)
        comp_summary.FSu_splw = Me.uplift_splw.Fsu_final_pro
        comp_summary.OK_uplift_splw = Me.uplift_splw.satisfactory_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(40, " Spillway Stability
Analysis against Uplift completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '*****************************************************
        'sluiceway stab analysis (uplift)*****************************************************
        With Me.input_geom_slcw
            .delta = Me.energy_dissipators.resultsb_sl_pro.delta
            .Kr = Me.input_Q_splw_slcw.Kr
            .Ks = Me.intake.Ks_pro
            .Kst = Me.input_intake.Kst
            .mh_delta = 2

            .sb_end = 9
            .sb_start = 8
            .Ssb = 0
            .str_start = 4
            ReDim .creep_path(input_geom_splw.creep_path.GetUpperBound(0))
            For i = 0 To .creep_path.GetUpperBound(0)  'new ile yepyeni yaratmaliyiz; cunku aksi taktirde
pointer assignment tehlikeli sonuc verecek
                .creep_path(i) = New c_point(input_geom_splw.creep_path(i).x,
input_geom_splw.creep_path(i).y)
            Next
            If Me.energy_dissipators.sb_common_pro = False Then 'if seperate still bas exist then redetermine
the sluiceway found elev by delta diff amount
                If Me.dim_splw_by_El = False Then
                    .creep_path(.sb_start).y += Me.energy_dissipators.delta_s_pro -
Me.energy_dissipators.delta_sl_pro
                    .creep_path(.sb_end).y += Me.energy_dissipators.delta_s_pro -
Me.energy_dissipators.delta_sl_pro
                End If
            End If
        End With
        uplift_slcw = New stab_uplift_sb(True, input_geom_slcw, input_mtrl.gwater, input_mtrl.gconc,
input_Fs.Fsu, input_mtrl.ured_perc)
        comp_summary.FSu_slcw = Me.uplift_slcw.Fsu_final_pro
        comp_summary.OK_uplift_slcw = Me.uplift_slcw.satisfactory_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(45, " Sluiceway Stability
Analysis against Uplift completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '*****************************************************
        'stab analysis (sliding and overturning )*********************************************
```

```
        sliding_overturning = New stab_sliding_and_overt(Me.uplift_splw.geom_for_so_pro, input_mtrl,
input_Fs, Me.uplift_splw.drains_add_pro, mh_ogee, tc_splw, crest_auto)
        comp_summary.FSs = Me.sliding_overturning.FSs_comp_pro
        comp_summary.OK_s = Me.sliding_overturning.OK_s_pro
        comp_summary.FSss = Me.sliding_overturning.FSss_comp_pro
        comp_summary.OK_ss = Me.sliding_overturning.OK_ss_pro
        comp_summary.MVoheel = Me.sliding_overturning.MVoheel_pro
        comp_summary.MVoheel_eu = Me.sliding_overturning.MVoheel_eu_pro
        comp_summary.MVotoe_eu = Me.sliding_overturning.MVotoe_eu_pro
        comp_summary.tc = Me.sliding_overturning.tc_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(50, " Spillway Stability
Analysis against Sliding and Overturning completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'Sidewalls (spillway side)**************************** *********************
        With Me.input_sidewalls_splw
            .fsoil = 0
            .Kus = Me.uplift_splw.Elsb_ds_pro
            .mh_free = 0
            .q_surch = 0
            .t2 = 0
            .y2max = Me.energy_dissipators.y2max_s_pro
            .El_base =
Me.uplift_splw.geom_for_so_pro.creep_path(Me.uplift_splw.geom_for_so_pro.sb_end).y 'bottom elev of
stillbas of simplified body of struct for sliding and overt is taken
        End With
        sidewalls_splw = New stab_sidewalls(input_mtrl, input_Fs, Me.input_sidewalls_splw)
        comp_summary.MVo_sw_splw = Me.sidewalls_splw.MVo_toe_pro
        comp_summary.FSs_sw_splw = Me.sidewalls_splw.FSs_comp_pro
        comp_summary.OK_s_sw_splw = Me.sidewalls_splw.OK_s_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(55, " Spillway Sidewalls
Computation completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'Sidewalls (sluiceway side)******************************** ******************
        With Me.input_sidewalls_slcw
            .fsoil = 0
            .Kus = Me.uplift_slcw.Elsb_ds_pro
            .mh_free = 0
            .q_surch = 0
            .t2 = 0
            .y2max = Me.energy_dissipators.y2max_sl_pro
            .El_base =
Me.uplift_slcw.geom_for_so_pro.creep_path(Me.uplift_slcw.geom_for_so_pro.sb_end).y
        End With
        sidewalls_slcw = New stab_sidewalls(input_mtrl, input_Fs, Me.input_sidewalls_slcw)
        comp_summary.MVo_sw_slcw = Me.sidewalls_slcw.MVo_toe_pro
        comp_summary.FSs_sw_slcw = Me.sidewalls_slcw.FSs_comp_pro
        comp_summary.OK_s_sw_slcw = Me.sidewalls_slcw.OK_s_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(60, " Sluiceway Sidewalls
Computation completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
        'Levees ****************************************************
        us_levees = New levees(Me.Q_splw_slcw.K_pro(0), Me.input_intake.Kst, Me.input_Q_splw_slcw.Lt,
z_levees, Me.input_Q_splw_slcw.Q(0), So_river, n_river, dx_levees)
        comp_summary.Lx_tot = Me.us_levees.wsprofile_pro.Lx_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(65, " Upstream Levees
Computation Completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '****************************************************
```

```
        'Appertunant facilities (riprap and flushing canal)
        riprap = New riprap_des(Me.energy_dissipators.resultsb_s_pro.y3, Me.input_Q_splw_slcw.Lt,
Me.input_Q_splw_slcw.Q(0), So_river, min_riprap_height, Ld_min)
        comp_summary.riprap_D = Me.riprap.D_pro
        comp_summary.riprap_Ld = Me.riprap.Ld_pro
        comp_summary.riprap_nrow = Me.riprap.nrow_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(70, " Riprap Design
completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        flushing_canal = New flushing_canal(Dm_flush, Dp_flush, n_flush, ks_flush, 1.65,
Me.intake.xsec_pro(4).km_xsec_p, Me.intake.xsec_pro(4).Kb_pro, 0.25, alfa_int, Me.input_Q_splw_slcw.Kr,
Me.energy_dissipators.resultsb_sl_pro.delta, So_river, Me.energy_dissipators.Lsb_pro +
Me.uplift_slcw.Lcutoff_tot_pro)
        comp_summary.flush_Dp = Me.flushing_canal.Dp_pro
        comp_summary.flush_So = Me.flushing_canal.So_pro
        comp_summary.flush_Lh = Me.flushing_canal.Lflush_h_pro
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(75, " Flushing Canal Design
completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        '--------------------------------------------------------------------------------
        comp_summary.accepted = Me.f_accepted(Me.comp_summary)
        If comp_summary.accepted = True Then
          If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(75, " Dweir is
SATISFACTORY", 3))
          add_inf(Me.comp_inf, Me.lview, Me.progbar)
        Else
          If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(75, " Dweir is
UNSATISFACTORY", 2))
          add_inf(Me.comp_inf, Me.lview, Me.progbar)
        End If
    End Sub
    Public Sub compute_w_div_fac_inp(ByVal div_fac As diversion_fac)
        Me.compute_wo_div_fac()
        Me.diversion_fac = div_fac
        comp_summary.B_div = Me.diversion_fac.opt_values_pro.b
        'cost calculations
************************************************************************
        With Me.input_dweir_cost
          .divfac_geom = div_fac
          .energy_dissp = Me.energy_dissipators
          .flush_geom = Me.flushing_canal
          .int_geom = Me.uplift_intake
          .int_hyd = Me.intake
          .Q_splw_slcw = Me.Q_splw_slcw
          .riprap_geom = Me.riprap
          .sidewalls_slcw_geom = Me.sidewalls_slcw
          .sidewalls_splw_geom = Me.sidewalls_splw
          .slcw_geom = Me.uplift_slcw
          .splw_geom = Me.uplift_splw
          .slide_overt = Me.sliding_overturning
        End With
        dweir_cost = New costs(input_dweir_cost)
        comp_summary.cost_int = Me.dweir_cost.cost_tot_int_pro
        comp_summary.cost_splw = Me.dweir_cost.cost_tot_splw_pro
        comp_summary.cost_slcw = Me.dweir_cost.cost_tot_slcw_pro
        comp_summary.cost_sidewalls = Me.dweir_cost.cost_sidewall_tot_pro
        comp_summary.cost_guidingwall = Me.dweir_cost.cost_guiding_wall_pro
        comp_summary.cost_riprap = Me.dweir_cost.cost_riprap_pro
        comp_summary.cost_flush = Me.dweir_cost.cost_flush_pro
        comp_summary.cost_bridge = Me.dweir_cost.cost_bridge_pro
        comp_summary.cost_divfac = Me.dweir_cost.cost_tot_div_pro
```

```
            comp_summary.cost_dweir = Me.dweir_cost.cost_tot_dweir_pro
            If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(95, " Cost Computations
completed successfully...", 0))
            add_inf(Me.comp_inf, Me.lview, Me.progbar)

'*************************************************************************************
        End Sub
        Public Sub compute()
            Me.compute_wo_div_fac()
            'diversion facility
*************************************************************************************
            diversion_fac = New diversion_fac(Me.input_diversion, Me.input_uCosts)
            comp_summary.B_div = Me.diversion_fac.opt_values_pro.b
            If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(90, " Diversion Facility
Computation completed successfully...", 0))
            add_inf(Me.comp_inf, Me.lview, Me.progbar)
            '*****************************************************
            'cost calculations **************************************************
            With Me.input_dweir_cost
                .divfac_geom = Me.diversion_fac
                .energy_dissp = Me.energy_dissipators
                .flush_geom = Me.flushing_canal
                .int_geom = Me.uplift_intake
                .int_hyd = Me.intake
                .Q_splw_slcw = Me.Q_splw_slcw
                .riprap_geom = Me.riprap
                .sidewalls_slcw_geom = Me.sidewalls_slcw
                .sidewalls_splw_geom = Me.sidewalls_splw
                .slcw_geom = Me.uplift_slcw
                .splw_geom = Me.uplift_splw
                .slide_overt = Me.sliding_overturning
            End With
            dweir_cost = New costs(input_dweir_cost)
            comp_summary.cost_int = Me.dweir_cost.cost_tot_int_pro
            comp_summary.cost_splw = Me.dweir_cost.cost_tot_splw_pro
            comp_summary.cost_slcw = Me.dweir_cost.cost_tot_slcw_pro
            comp_summary.cost_sidewalls = Me.dweir_cost.cost_sidewall_tot_pro
            comp_summary.cost_guidingwall = Me.dweir_cost.cost_guiding_wall_pro
            comp_summary.cost_riprap = Me.dweir_cost.cost_riprap_pro
            comp_summary.cost_flush = Me.dweir_cost.cost_flush_pro
            comp_summary.cost_bridge = Me.dweir_cost.cost_bridge_pro
            comp_summary.cost_divfac = Me.dweir_cost.cost_tot_div_pro
            comp_summary.cost_dweir = Me.dweir_cost.cost_tot_dweir_pro
            If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(95, " Cost Computations
completed successfully...", 0))
            add_inf(Me.comp_inf, Me.lview, Me.progbar)

'*************************************************************************************
        End Sub
#End Region
#Region "Properties"
        Public ReadOnly Property comp_summary_pro() As optimization_try_output_data
            Get
                Return Me.comp_summary
            End Get
        End Property
        Public ReadOnly Property intake_pro() As intake
            Get
                Return Me.intake
            End Get
        End Property
```

```
Public ReadOnly Property Q_splw_slcw_pro() As splw_slcw_Q
    Get
        Return Me.Q_splw_slcw

    End Get
End Property
Public ReadOnly Property energy_dissipators_pro() As energy_dissp
    Get
        Return Me.energy_dissipators
    End Get
End Property
Public ReadOnly Property seepage_pro() As seepage_analysis
    Get
        Return Me.seepage
    End Get
End Property
Public ReadOnly Property uplift_intake_pro() As stab_uplift_sb
    Get
        Return Me.uplift_intake
    End Get
End Property
Public ReadOnly Property uplift_splw_pro() As stab_uplift_sb
    Get
        Return Me.uplift_splw
    End Get
End Property
Public ReadOnly Property uplift_slcw_pro() As stab_uplift_sb
    Get
        Return Me.uplift_slcw
    End Get
End Property
Public ReadOnly Property sliding_overturning_pro() As stab_sliding_and_overt
    Get
        Return Me.sliding_overturning
    End Get
End Property
Public ReadOnly Property sidewalls_splw_pro() As stab_sidewalls
    Get
        Return Me.sidewalls_splw
    End Get
End Property
Public ReadOnly Property sidewalls_slcw_pro() As stab_sidewalls
    Get
        Return Me.sidewalls_slcw
    End Get
End Property
Public ReadOnly Property us_levees_pro() As levees
    Get
        Return Me.us_levees
    End Get
End Property
Public ReadOnly Property diversion_fac_pro() As diversion_fac
    Get
        Return Me.diversion_fac
    End Get
End Property
Public ReadOnly Property riprap_pro() As riprap_des
    Get
        Return Me.riprap
    End Get
End Property
```

```
    Public ReadOnly Property flushing_canal_pro() As flushing_canal
      Get
        Return Me.flushing_canal
      End Get
    End Property
    Public ReadOnly Property dweir_cost_pro() As costs
      Get
        Return Me.dweir_cost
      End Get
    End Property
#End Region
#Region "Constructors"
    Public Sub New(ByVal input As dweir_input_data)
      Me.lview = Nothing
      Me.progbar = Nothing
      Me.comp_inf = Nothing
      With input
        Me.alfa_int = .alfa_int
        Me.C = .C
        Me.Dm_flush = .Dm_flush
        Me.Dp_flush = .Dp_flush
        Me.dx_levees = .dx_levees
        Me.El_int = .El_int
        Me.El_spl = .El_spl
        Me.Hsp_int = .Hsp_int
        Me.Hsp_spl = .Hsp_spl
        Me.input_diversion = .input_diversion
        Me.input_dweir_cost = .input_dweir_cost
        Me.input_energy_dissipators = .input_energy_dissipators
        Me.input_Fs = .input_Fs
        Me.input_geom_intake = .input_geom_intake
        Me.input_geom_slcw = .input_geom_slcw
        Me.input_geom_splw = .input_geom_splw
        Me.input_intake = .input_intake
        Me.input_mtrl = .input_mtrl
        Me.input_Q_splw_slcw = .input_Q_splw_slcw
        Me.input_sidewalls_slcw = .input_sidewalls_slcw
        Me.input_sidewalls_splw = .input_sidewalls_splw
        Me.input_uCosts = .input_uCosts
        Me.ks_flush = .ks_flush
        Me.L_int = .L_int
        Me.L_spl = .L_spl
        Me.Ld_min = .Ld_min
        Me.Lub_int = .Lub_int
        Me.Lub_spl = .Lub_spl
        Me.min_riprap_height = .min_riprap_height
        Me.n_flush = .n_flush
        Me.n_river = .n_river
        Me.So_river = .So_river
        Me.tc_splw = .tc_splw
        Me.crest_auto = .crest_auto
        Me.mh_ogee = .mh_ogee
        Me.z_levees = .z_levees
        Me.dim_int_by_El = .dim_int_by_El
        Me.dim_splw_by_El = .dim_splw_by_El
      End With
    End Sub
    Public Sub New(ByVal input As dweir_input_data, ByVal inp_comp_inf As Queue, ByVal inp_lview As
System.Windows.Forms.ListView, ByVal inp_progbar As System.Windows.Forms.ProgressBar)
      Me.lview = inp_lview
      Me.progbar = inp_progbar
```

```
            Me.comp_inf = inp_comp_inf
            With input
                Me.alfa_int = .alfa_int
                Me.C = .C
                Me.Dm_flush = .Dm_flush
                Me.Dp_flush = .Dp_flush
                Me.dx_levees = .dx_levees
                Me.El_int = .El_int
                Me.El_spl = .El_spl
                Me.Hsp_int = .Hsp_int
                Me.Hsp_spl = .Hsp_spl
                Me.input_diversion = .input_diversion
                Me.input_dweir_cost = .input_dweir_cost
                Me.input_energy_dissipators = .input_energy_dissipators
                Me.input_Fs = .input_Fs
                Me.input_geom_intake = .input_geom_intake
                Me.input_geom_slcw = .input_geom_slcw
                Me.input_geom_splw = .input_geom_splw
                Me.input_intake = .input_intake

                Me.input_mtrl = .input_mtrl
                Me.input_Q_splw_slcw = .input_Q_splw_slcw
                Me.input_sidewalls_slcw = .input_sidewalls_slcw
                Me.input_sidewalls_splw = .input_sidewalls_splw
                Me.input_uCosts = .input_uCosts
                Me.ks_flush = .ks_flush
                Me.L_int = .L_int
                Me.L_spl = .L_spl
                Me.Ld_min = .Ld_min
                Me.Lub_int = .Lub_int
                Me.Lub_spl = .Lub_spl
                Me.min_riprap_height = .min_riprap_height
                Me.n_flush = .n_flush
                Me.n_river = .n_river
                Me.So_river = .So_river
                Me.tc_splw = .tc_splw
                Me.crest_auto = .crest_auto
                Me.mh_ogee = .mh_ogee
                Me.z_levees = .z_levees
                Me.dim_int_by_El = .dim_int_by_El
                Me.dim_splw_by_El = .dim_splw_by_El
            End With
        End Sub
#End Region
    End Class
    <Serializable()> Public Class optimize_Bmain
        Public Shared max_iter_Bop As Integer = 100
        Public Shared inc_Bop = 0.1
#Region "Private variables"
        <NonSerialized()> Private lview As System.Windows.Forms.ListView
        <NonSerialized()> Private progbar As System.Windows.Forms.ProgressBar
        Private comp_inf As Queue
        'inputs
        Private input_dweir As dweir_input_data
        Private index_opt As Integer
        Private index_opt2 As Integer
        Private error_iter As Boolean
        Private div_fac As diversion_fac
        Private dweir_try(0) As whole_dweir
        Private dweir_try_OK(0) As whole_dweir 'accepted trys
#End Region
```

```
#Region "Class interface"
    Public Sub compute()
        Dim i As Integer = 0
        Dim i_OK As Integer
        Dim j As Integer
        Dim k As Integer
        'compute div_fac seperately, it is independent from the whole dweir
        div_fac = New diversion_fac(Me.input_dweir.input_diversion, Me.input_dweir.input_uCosts)
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(15, " Diversion Facility
computations completed successfully...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        'start value for Bmain
        With input_dweir.input_intake
            .Bop = 1.0 '0.25
            .B1 = 2 * .Bop
            .Bs = .B1 + 1
        End With
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(10, "Try-" & i + 1 & " : B="
& input_dweir.input_intake.Bop & " m. Starts...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        Me.dweir_try(0) = New whole_dweir(input_dweir)
        Me.dweir_try(0).compute_w_div_fac_inp(div_fac) 'dont forget to use compute (for computations it is
necessary)
        'initial accepted value
        Do Until (Me.dweir_try(i).comp_summary_pro.accepted = True)
            If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25, "Try-" & i + 1 & " :
B=" & input_dweir.input_intake.Bop & " m. Rejected", 2))
            add_inf(Me.comp_inf, Me.lview, Me.progbar)
            i += 1
            If i >= max_iter Then
                Exit Do
            End If
            ReDim Preserve dweir_try(dweir_try.GetUpperBound(0) + 1)
            With input_dweir.input_intake
                .Bop += inc_Bop
                .B1 = 2 * .Bop
                .Bs = .B1 + 1
            End With
            If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Try-" & i + 1 & "
: B=" & input_dweir.input_intake.Bop & " m. Starts...", 0))
            add_inf(Me.comp_inf, Me.lview, Me.progbar)
            Me.dweir_try(i) = New whole_dweir(input_dweir)
            Me.dweir_try(i).compute_w_div_fac_inp(div_fac)  'dont forget to use compute (for computations it
is necessary)
        Loop
        i_OK = 0
        k = i
        'son birakilani yeniden kopyaliyoruz
        Me.dweir_try_OK(0) = New whole_dweir(input_dweir)
        Me.dweir_try_OK(0).compute_w_div_fac_inp(div_fac)  'dont forget to use compute (for computations
it is necessary)
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Try-" & i + 1 & " :
B=" & input_dweir.input_intake.Bop & " m. Accepted...", 3))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        Do
            Do
                'only for visuality
                If (i <> k) Then
                    If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf((i + 2) / 20 * 100,
"Try-" & i + 1 & " : B=" & input_dweir.input_intake.Bop & " m. Rejected...", 2))
                    add_inf(Me.comp_inf, Me.lview, Me.progbar)
```

```
        End If
        i += 1
        If i >= max_iter Then
          Exit Do
        End If
        ReDim Preserve dweir_try(dweir_try.GetUpperBound(0) + 1)
        With input_dweir.input_intake
          .Bop += inc_Bop
          .B1 = 2 * .Bop
          .Bs = .B1 + 1
        End With
        If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Try-" & i + 1 &
" : B=" & input_dweir.input_intake.Bop & " m. Starts...", 0))
        add_inf(Me.comp_inf, Me.lview, Me.progbar)
        Me.dweir_try(i) = New whole_dweir(input_dweir)
        Me.dweir_try(i).compute_w_div_fac_inp(div_fac)  'dont forget to use compute (for computations
it is necessary)
        '
      Loop Until ((Me.dweir_try(i).comp_summary_pro.accepted = True))
      i_OK += 1
      If i >= max_iter_Bop Then
        Exit Do
      End If
      ReDim Preserve dweir_try_OK(dweir_try_OK.GetUpperBound(0) + 1)
      Me.dweir_try_OK(i_OK) = New whole_dweir(input_dweir)
      Me.dweir_try_OK(i_OK).compute_w_div_fac_inp(div_fac)  'dont forget to use compute (for
computations it is necessary)
      If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Try-" & i + 1 & "
: B=" & input_dweir.input_intake.Bop & " m. Accepted...", 3))
      add_inf(Me.comp_inf, Me.lview, Me.progbar)
    Loop While ((Me.dweir_try_OK(i_OK).comp_summary_pro.cost_dweir < Me.dweir_try_OK(i_OK -
1).comp_summary_pro.cost_dweir))
    index_opt = i_OK - 1
    index_opt2 = i - 1
    If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Optimum width
found : Try-" & i + 1 & " : B=" & Me.dweir_try_OK(index_opt).comp_summary_pro.B_main & " m. ...", 0))
    add_inf(Me.comp_inf, Me.lview, Me.progbar)
    If (index_opt = max_iter_Bop) Then
      error_iter = True 'means that an optimal solution curve can't be reached (iteration not enough)
    Else
      error_iter = False
      'in order to see a good curve; some extra data generated beyond the optimum value
      If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Additional
iterations started to construct the optimization curve", 0))
      add_inf(Me.comp_inf, Me.lview, Me.progbar)
      For j = i_OK + 1 To i_OK + 10
        k = i
        Do
          'only for visuality
          If (i <> k) Then
            If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf((i + 2) / 20 * 100,
"Try-" & i + 1 & " : B=" & input_dweir.input_intake.Bop & " m. Rejected...", 2))
            add_inf(Me.comp_inf, Me.lview, Me.progbar)
          End If
          i += 1
          If i >= max_iter Then
            Exit Do
          End If
          ReDim Preserve dweir_try(dweir_try.GetUpperBound(0) + 1)
          With input_dweir.input_intake
            .Bop += inc_Bop
```

```
                        .B1 = 2 * .Bop
                        .Bs = .B1 + 1
                    End With
                    If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, "Try-" & i + 1
& ": B=" & input_dweir.input_intake.Bop & " m. ...Starts", 0))
                    add_inf(Me.comp_inf, Me.lview, Me.progbar)
                    Me.dweir_try(i) = New whole_dweir(input_dweir)
                    Me.dweir_try(i).compute_w_div_fac_inp(div_fac)  'dont forget to use compute (for
computations it is necessary)
                    '
                Loop Until (Me.dweir_try(i).comp_summary_pro.accepted = True)
                ReDim Preserve dweir_try_OK(dweir_try_OK.GetUpperBound(0) + 1)
                Me.dweir_try_OK(j) = New whole_dweir(input_dweir)
                Me.dweir_try_OK(j).compute_w_div_fac_inp(div_fac)  'dont forget to use compute (for
computations it is necessary)
                If Not IsNothing(Me.comp_inf) Then Me.comp_inf.Enqueue(f_comp_inf(25 + i, " B=" &
input_dweir.input_intake.Bop & " m. ...Accepted", 3))
                add_inf(Me.comp_inf, Me.lview, Me.progbar)
                '
            Next
        End If
    End Sub
#End Region
#Region "Properties"
    Public ReadOnly Property error_iter_pro() As Boolean
        Get
            Return error_iter
        End Get
    End Property
    Public ReadOnly Property dweir_try_pro() As whole_dweir()
        Get
            Return dweir_try
        End Get
    End Property
    Public ReadOnly Property dweir_try_OK_pro() As whole_dweir()
        Get
            Return dweir_try_OK
        End Get
    End Property
    Public ReadOnly Property opt_dweir_pro() As whole_dweir
        Get
            Return dweir_try_OK(index_opt)
        End Get
    End Property
    Public ReadOnly Property opt_dweir_summarypro() As optimization_try_output_data
        Get
            Return dweir_try_OK(index_opt).comp_summary_pro
        End Get
    End Property
#End Region
#Region "Constructors"
    Public Sub New(ByVal input1 As dweir_input_data)
        Me.lview = Nothing
        Me.progbar = Nothing
        Me.comp_inf = Nothing
        input_dweir = input1
        input_dweir.crest_auto = True 'herzaman automatically calculate
        'input_dweir.input_sidewalls_slcw.change_dim_type = 2
        'input_dweir.input_sidewalls_splw.change_dim_type = 2
        'input_dweir.tc_splw = 0
    End Sub
```

```
        Public Sub New(ByVal input1 As dweir_input_data, ByVal inp_comp_inf As Queue, ByVal inp_lview
As System.Windows.Forms.ListView, ByVal inp_progbar As System.Windows.Forms.ProgressBar)
            Me.lview = inp_lview
            Me.progbar = inp_progbar
            Me.comp_inf = inp_comp_inf
            input_dweir = input1
            input_dweir.crest_auto = True 'herzaman automatically calculate
            'input_dweir.input_sidewalls_slcw.change_dim_type = 2
            'input_dweir.input_sidewalls_splw.change_dim_type = 2
        End Sub
#End Region
    End Class
    <Serializable()> Public Class error_hand
        Public Shared Sub add_error_inf(ByVal lview As System.Windows.Forms.ListView)
        End Sub
        Public Shared Sub add_inf(ByVal inf_coll As Queue, ByVal lview As
System.Windows.Forms.ListView, ByVal progbar As System.Windows.Forms.ProgressBar)
            Dim i As Integer
            Dim inf As computation_information
            If (IsNothing(lview) = False And IsNothing(progbar) = False And IsNothing(inf_coll) = False) Then
                lview.Items.Insert(0, lview.Items.Count)
                inf = CType(inf_coll.Dequeue, computation_information)
                lview.Items(0).SubItems.Add(inf.message)
                If inf.percent <= 100 Then
                    progbar.Value = inf.percent
                Else
                    progbar.Value = 100
                End If
                Select Case inf.state
                    Case 0 'normal exec
                        lview.Items(0).ForeColor = System.Drawing.Color.Green
                    Case 1 'error
                        lview.Items(0).ForeColor = System.Drawing.Color.Red
                    Case 2 'warning
                        lview.Items(0).ForeColor = System.Drawing.Color.DarkRed
                    Case 3 'accepted
                        lview.Items(0).ForeColor = System.Drawing.Color.Blue
                End Select
            End If
        End Sub
    End Class
#End Region
End Namespace
'*---------------------------------------------------------------------------------------------------------------------------*
'|                                        END OF CLASS-1                                                                       |
'*---------------------------------------------------------------------------------------------------------------------------*


'*---------------------------------------------------------------------------------------------------------------------------*
'|                                        FORM-1 : Form1.vb                                                                    |
'*---------------------------------------------------------------------------------------------------------------------------*
Public Class frm_about
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
```

```
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
   'This part of code is generated automatically. Details are hidden.
#End Region
    Private Sub LinkLabel1_LinkClicked(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.LinkLabelLinkClickedEventArgs) Handles LinkLabel1.LinkClicked
        e.Link.LinkData = "www.metu.edu.tr"
        System.Diagnostics.Process.Start(e.Link.LinkData.ToString())
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        Me.Dispose()
    End Sub
    Private Sub LinkLabel2_LinkClicked(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.LinkLabelLinkClickedEventArgs) Handles LinkLabel2.LinkClicked
        e.Link.LinkData = "mailto:khturan@hotmail.com"
        System.Diagnostics.Process.Start(e.Link.LinkData.ToString())
    End Sub
    Private Sub frm_about_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
    End Sub
    Private Sub LinkLabel3_LinkClicked(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.LinkLabelLinkClickedEventArgs) Handles LinkLabel3.LinkClicked
        e.Link.LinkData = "www.ce.metu.edu.tr"
        System.Diagnostics.Process.Start(e.Link.LinkData.ToString())
    End Sub
End Class
'*------------------------------------------------------------------------------------------------------------------------*
'|                                        END OF FORM-1                                                                   |
'*------------------------------------------------------------------------------------------------------------------------*


'*------------------------------------------------------------------------------------------------------------------------*
'|                                        FORM-10 : Form10.vb                                                             |
'*------------------------------------------------------------------------------------------------------------------------*
Public Class frm_prj_summary
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
```

```
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
    'This part of code is generated automaticallt. Details are hidden.
#End Region
    Private Sub frm_prj_summary_Load(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles MyBase.Load
        Me.TextBox1.Text = frm_main.prj_type.prj_title
        Me.TextBox2.Text = frm_main.prj_type.prj_eng
        Me.TextBox3.Text = frm_main.prj_type.prj_def
        Try 'if invalid time is loaded; then catch error and make the value as todays date
            Me.DateTimePicker1.Value = frm_main.prj_type.prj_date
        Catch
            Me.DateTimePicker1.Value = Today
        End Try
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        Me.Button1.Enabled = False
        frm_main.prj_type.prj_title = Me.TextBox1.Text
        frm_main.prj_type.prj_eng = Me.TextBox2.Text
        frm_main.prj_type.prj_def = Me.TextBox3.Text
        frm_main.prj_type.prj_date = Me.DateTimePicker1.Value
        Me.Dispose()
    End Sub
    Private Sub TextBox1_TextChanged(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles TextBox1.TextChanged
    End Sub
    Private Sub TextBox2_TextChanged(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles TextBox2.TextChanged
    End Sub
    Private Sub TextBox3_TextChanged(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles TextBox3.TextChanged
    End Sub
    Private Sub DateTimePicker1_ValueChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles DateTimePicker1.ValueChanged
    End Sub
    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button2.Click
        Me.Dispose()
    End Sub
End Class
'*-------------------------------------------------------------------------------------------------------------------------------*
'|                                        END OF FORM-10                                                                          |
'*-------------------------------------------------------------------------------------------------------------------------------*


'*-------------------------------------------------------------------------------------------------------------------------------*
'|                                        FORM-12 : Form12.vb                                                                     |
'*-------------------------------------------------------------------------------------------------------------------------------*
Public Class frm_splash
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
```

```
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
    ‘This part of code is generated automatically. Details are hidden.
#End Region
    Private counter As Integer = 0
    Private frm_mainc As New frm_main()
    Private Sub Timer1_Tick(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Timer1.Tick
        counter += 1
        If counter = 5 Then
            Me.Timer1.Enabled = False
            frm_mainc.Show()
            Me.Hide()
        End If
    End Sub
End Class
'*-------------------------------------------------------------------------------------------------------------------*
'|                                        END OF FORM-12                                                             |
'*-------------------------------------------------------------------------------------------------------------------*


'*-------------------------------------------------------------------------------------------------------------------*
'|                                        FORM-13 : Form13.vb                                                        |
'*-------------------------------------------------------------------------------------------------------------------*
Imports dweir_code.General_Hydraulic_Functions
Imports dweir_code.General_Hydraulic_Functions.OCH_func
Imports dweir_code.intake_design
Imports dweir_code.splw_slcw_design
Imports dweir_code.stability_analysis
Imports dweir_code.Appurtenant_fac
Imports dweir_code.levees_and_diversion
Imports dweir_code.cost_computations
Imports dweir_code.computations
Imports System.Math
Imports System.IO
Imports Microsoft.VisualBasic.Strings
Imports System.Runtime.Serialization
Imports System.Runtime.Serialization.Formatters.Binary
Public Class frm_main
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
```

```
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
    ‘This part of the code is generated automatically. Details are hidden.
#End Region
#Region "Program main variables, objects and data structures "
    'project type 'note this is a user def data structure
    Public Shared prj_type As New project_type()
    Public Shared output_tables_index As Integer '0:intake; 1:spilway_slcw_q,....
    Public Shared obj_state As New objects_state()
    'input data structures
    Public Shared inp_intake As New intake_input_data()
    Public Shared inp_Q_splw_slcw As New splw_slcw_Q_input_data()
    Public Shared inp_energy_dissp As New energy_dissp_input_data()
    Public Shared inp_int_geom As New stab_geom_input_data()
    Public Shared inp_splw_geom As New stab_geom_input_data()
    Public Shared inp_slcw_geom As New stab_geom_input_data()
    Public Shared inp_sw_splw As New stab_sidewall_input_data()
    Public Shared inp_sw_slcw As New stab_sidewall_input_data()
    Public Shared inp_mtrl As New stab_mtrl_input_data()
    Public Shared inp_FS As New stab_Fs_input_data()
    Public Shared inp_unit_costs As New unit_costs_input_data()
    Public Shared inp_div As New diversion_input_data()
    Public Shared inp_cost_comp As New costs_input_data()
    'input data main
    Public Shared Qirr As Single
    Public Shared So_main As Single
    Public Shared K1 As Single
    Public Shared B_main As Single
    Public Shared n_conc As Single
    Public Shared mh_main As Single
    Public Shared n_river As Single
    Public Shared Kt As Single
    Public Shared Kr As Single
    Public Shared So_river As Single
    Public Shared Q() As Single
    Public Shared Kd() As Single
    Public Shared profile() As String
    Public Shared C As Single
    Public Shared Saf As Single
    Public Shared Sac As Single
    Public Shared f As Single
    Public Shared Tall As Single
    Public Shared Fi As Single
    Public Shared kh As Single
    Public Shared kv As Single
    Public Shared gconc As Single
    Public Shared gwater As Single
    Public Shared teta As Single
```

```
    Public Shared gdry As Single
    Public Shared gsat As Single
    'input data intake-1
    Public Shared Lc As Single
    Public Shared L23 As Single
    Public Shared np As Integer
    Public Shared tp As Single
    Public Shared tg As Single
    Public Shared Lp As Single
    Public Shared npi As Integer
    Public Shared tpi As Single
    Public Shared Lpi As Single
    Public Shared tgi As Single
    Public Shared tr As Single
    Public Shared Df As Single
    Public Shared Sd As Single
    Public Shared Dm As Single
    Public Shared r As Single
    Public Shared Ct As Single
    Public Shared Cc As Single
    Public Shared u5 As Single
    'input data intake-2
    Public Shared Lub_int As Single
    Public Shared Hsp_int As Single
    Public Shared Dsu As Single
    Public Shared maxDsu As Single
    Public Shared Dsd As Single
    Public Shared minDu As Single
    Public Shared maxDu As Single
    Public Shared L_int(4) As Single
    Public Shared El_int(6) As Single
    Public Shared dim_int_by_El As Boolean 'if dim by found elev or slab thicknesses
    'input data spl_slcw-1
    Public Shared Lt As Single
    Public Shared nsl As Integer
    Public Shared Le As Single
    Public Shared d As Single
    Public Shared tsl As Single
    Public Shared brdg_exist As Boolean 'if there exist bridge or not
    Public Shared np_brdg As Integer
    Public Shared tp_brdg As Single
    Public Shared Lp_brdg As Integer
    Public Shared tslab_brdg As Integer  'slab thickness of bridge
    Public Shared wslab_brdg As Integer  'slab width of bridge
    Public Shared Kp As Single
    Public Shared Ka As Single
    Public Shared Lp_slcw As Single
    Public Shared tg_slcw As Single
    'input data spl_slcw-2
    Public Shared tc_splw_auto As Boolean  'if program calculates crest thickness automatically
    Public Shared tc_splw As Single
    Public Shared Lub_spl As Single
    Public Shared Hsp_spl As Single
    Public Shared mh_spl As Single 'mh_ogee
    Public Shared L_spl(4) As Single
    Public Shared El_spl(6) As Single
    Public Shared dim_splw_by_El As Boolean 'if dim by found elev or slab thicknesses
    'input data sidewalls and levees
    Public Shared coulomb_type As Boolean 'gravity=coulomb=true ; cantilever=rankine=false
    Public Shared sw_comp_type As Byte  '0:no dim change; 1:change if not satisfy ; 2:find the optimum by
start with zero
```

```
Public Shared tc_sw As Single
Public Shared tslab_sw As Single
Public Shared tb_sw As Single
Public Shared B_sw As Single
Public Shared gwd_sw As Single
Public Shared dx_levee As Single
Public Shared z_levee As Single
'input data diversion
Public Shared Ldc As Single
Public Shared mh_div As Single
Public Shared Kta As Single
Public Shared Qdiv As Single
Public Shared Ktb As Single
Public Shared Kb As Single
Public Shared delta_div As Single
Public Shared mh_uc As Single
Public Shared mh_dc As Single
Public Shared uCe As Single
Public Shared uCl As Single
Public Shared uCex As Single
Public Shared uCcore As Single
Public Shared uCper As Single
Public Shared dx_div As Single
'input data appertunant fac
Public Shared t_ripmin As Single
Public Shared Ld_ripmin As Single
Public Shared Dm_flush As Single
Public Shared Dp_flush As Single
Public Shared ks_flush As Single
Public Shared n_flush As Single
Public Shared alfa_flush As Single
'safety criteria
Public Shared FSu As Single
Public Shared FSs As Single
Public Shared FSss As Single
Public Shared FSo As Single
Public Shared FSs_sw As Single
Public Shared Vmax As Single
Public Shared Vmin As Single
'unit cost values
Public Shared uCco As Single
Public Shared uCcs As Single
Public Shared uCrip As Single
'program core objects (pointers)*****************************************
Public Shared intake_des As intake
Public Shared splw_Q As splw_slcw_Q
Public Shared energy_dissp As energy_dissp
Public Shared riprap_des As riprap_des
Public Shared flush_des As flushing_canal
Public Shared seepage_des As seepage_analysis
Public Shared int_uplift As stab_uplift_sb
Public Shared splw_uplift As stab_uplift_sb
Public Shared slcw_uplift As stab_uplift_sb
Public Shared stab_slide_overt As stab_sliding_and_overt
Public Shared stab_sw_splw As stab_sidewalls
Public Shared stab_sw_slcw As stab_sidewalls
Public Shared levees_des As levees
Public Shared div_fac As diversion_fac
Public Shared costs As costs
Public Shared summary_result As optimization_try_output_data
Public Shared try_summary_results() As optimization_try_output_data
```

```
    Public Shared try_summary_results_OK() As optimization_try_output_data
#End Region
#Region "form variables (to access to other forms)"
    'form objects
    ' Public Shared frm_collection As New Collection()
    Public Shared frm_prj_typec As frm_prj_type
    Public Shared frm_inputc As frm_input
    Public Shared frm_computec As frm_compute
    Public Shared frm_out_intc As frm_outputs
    Public Shared frm_prj_summaryc As frm_prj_summary
#End Region
    Private prj_path As String = "" 'to handle the project file path; initially it is set empty meaning that not
saved yet
    Private prj_changed As Boolean = False 'if it was changed by inputting data
    Private Sub frm_main_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        'need for new custom datagrid control
        Me.StatusBarPanel1.Text = "WINDWEIR"
        Me.StatusBarPanel2.Text = "Project Title:  "
        Me.StatusBarPanel3.Text = "Project File:  "
    End Sub
    Private Sub MenuItem1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem1.Click
    End Sub
    Private Sub MenuItem3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem3.Click
    End Sub
    Private Sub MenuItem4_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem4.Click
    End Sub
    Private Sub MenuItem11_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem11.Click
    End Sub
    Private Sub MenuItem13_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem13.Click
    End Sub
    Private Sub MenuItem14_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem14.Click
        Application.Exit()
    End Sub
    Private Sub MenuItem6_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem6.Click
    End Sub
    Private Sub MenuItem8_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem8.Click
    End Sub
    Private Sub MenuItem15_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem15.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 0
    End Sub
    Private Sub MenuItem19_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem19.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 7
    End Sub
    Private Sub MenuItem20_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem20.Click
    End Sub
    Private Sub MenuItem27_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem27.Click
```

```
    End Sub
#Region "My Procedures"
#Region "new project"
    Private Sub new_project()
        reset_all_variables()
        frm_prj_typec = New frm_prj_type()
        frm_prj_typec.ShowDialog()
        Me.initialize_frm_variables(Me.prj_type)
        Me.StatusBarPanel2.Text = "Project Title:  " & prj_type.prj_title
        Me.StatusBarPanel3.Text = "Project File:  " & prj_path
    End Sub
    Private Sub reset_all_variables()
        'firstly clear all forms
        Dim frm_childs As Form
        'unload all child forms
        For Each frm_childs In Me.MdiChildren
            If Not (frm_childs Is Nothing) Then
                frm_childs.Dispose()
            End If
        Next
        'unload unchild forms by hand
        If Not (frm_prj_summaryc Is Nothing) Then

            frm_prj_summaryc.Dispose()
        End If
        If Not (frm_computec Is Nothing) Then
            frm_computec.Dispose()
        End If
        Me.frm_inputc = Nothing
        Me.frm_computec = Nothing
        Me.frm_out_intc = Nothing
        Me.frm_prj_summaryc = Nothing
        Me.prj_path = ""
        prj_type = New project_type()
        'input data structures
        inp_intake = New intake_input_data()
        inp_Q_splw_slcw = New splw_slcw_Q_input_data()
        inp_energy_dissp = New energy_dissp_input_data()
        inp_int_geom = New stab_geom_input_data()
        inp_splw_geom = New stab_geom_input_data()
        inp_slcw_geom = New stab_geom_input_data()
        inp_sw_splw = New stab_sidewall_input_data()
        inp_sw_slcw = New stab_sidewall_input_data()
        inp_mtrl = New stab_mtrl_input_data()
        inp_FS = New stab_Fs_input_data()
        inp_unit_costs = New unit_costs_input_data()
        inp_div = New diversion_input_data()
        inp_cost_comp = New costs_input_data()
        'input data main
        Qirr = 0
        So_main = 0
        K1 = 0
        B_main = 0
        n_conc = 0
        mh_main = 0
        n_river = 0
        Kt = 0
        Kr = 0
        So_river = 0
        Q = Nothing
        Kd = Nothing
```

```
profile = Nothing
C = 0
Saf = 0
Sac = 0
f = 0
Tall = 0
Fi = 0
kh = 0
kv = 0
gconc = 0
gwater = 0
teta = 0
gdry = 0
gsat = 0
'input data intake-1
Lc = 0
L23 = 0
np = 0
tp = 0
tg = 0
Lp = 0
npi = 0
tpi = 0
Lpi = 0
tgi = 0
tr = 0
Df = 0

Sd = 0
Dm = 0
r = 0
Ct = 0
Cc = 0
u5 = 0
'input data intake-2
Lub_int = 0
Hsp_int = 0
Dsu = 0
maxDsu = 0
Dsd = 0
minDu = 0
maxDu = 0
L_int = Nothing
El_int = Nothing
dim_int_by_El = False 'if dim by found elev or slab thicknesses
'input data spl_slcw-1
Lt = 0
nsl = 0.0R
Le = 0
d = 0
tsl = 0
brdg_exist = False 'if there exist bridge or not
np_brdg = 0
tp_brdg = 0
Lp_brdg = 0
tslab_brdg = 0 'slab thickness of bridge
wslab_brdg = 0 'slab width of bridge
Kp = 0
Ka = 0
Lp_slcw = 0
tg_slcw = 0
```

```
'input data spl_slcw-2
tc_splw_auto = False 'if program calculates crest thickness automatically
tc_splw = 0
Lub_spl = 0
Hsp_spl = 0
mh_spl = 0 'mh_ogee
L_spl(4) = Nothing
El_spl(6) = Nothing
dim_splw_by_El = False 'if dim by found elev or slab thicknesses
'input data sidewalls and levees
coulomb_type = False 'gravity=coulomb=true ; cantilever=rankine=false
sw_comp_type = 0 '0:no dim change; 1:change if not satisfy ; 2:find the optimum by start with zero
tc_sw = 0
tslab_sw = 0
tb_sw = 0
B_sw = 0
gwd_sw = 0
dx_levee = 0
z_levee = 0
'input data diversion
Ldc = 0
mh_div = 0
Kta = 0
Qdiv = 0
Ktb = 0
Kb = 0
delta_div = 0
mh_uc = 0
mh_dc = 0
uCe = 0
uCl = 0
uCex = 0
uCcore = 0
uCper = 0
dx_div = 0
'input data appertunant fac
t_ripmin = 0
Ld_ripmin = 0
Dm_flush = 0
Dp_flush = 0
ks_flush = 0
n_flush = 0
alfa_flush = 0
'safety criteria
FSu = 0
FSs = 0
FSss = 0
FSo = 0
FSs_sw = 0
Vmax = 0
Vmin = 0
'unit cost values
uCco = 0
uCcs = 0
uCrip = 0
'program core objects (pointers)*****************************************
intake_des = Nothing
splw_Q = Nothing
energy_dissp = Nothing
riprap_des = Nothing
flush_des = Nothing
```

```
        seepage_des = Nothing
        int_uplift = Nothing
        splw_uplift = Nothing
        slcw_uplift = Nothing
        stab_slide_overt = Nothing
        stab_sw_splw = Nothing
        stab_sw_slcw = Nothing
        costs = Nothing
        levees_des = Nothing
        div_fac = Nothing
        'refresh the states
        frm_computec.load_obj_states()
    End Sub
    Private Sub initialize_frm_variables(ByVal prj_type As project_type)
        With Me
            If prj_type.prj_main_module = True Then 'main modules
                If prj_type.prob_type = 0 Then 'dweir with overflow spillw
                    .frm_inputc = New frm_input()
                    .frm_out_intc = New frm_outputs()
                    .frm_inputc.Show()
                ElseIf prj_type.prob_type = 1 Then 'gated dweir
                    'code to add in future
                End If
            Else 'secondary modules
                'code to add in future
            End If
        End With
    End Sub
#End Region
#Region "open project procedures"
    Private Sub open_project()
        Dim open_diag As New OpenFileDialog()
        With open_diag
            .InitialDirectory = Application.ExecutablePath
            .DefaultExt = "dwr"
            .FileName = "project1"
            .Filter = "DWR Files" & " (*.dwr)|*.dwr|All Files (*.*)|*.*"
            If .ShowDialog = DialogResult.OK Then
                Me.open_project_data(.FileName)
            End If
        End With
        Me.StatusBarPanel2.Text = "Project Title:" & prj_type.prj_title
        Me.StatusBarPanel3.Text = "Project File:" & prj_path
    End Sub
    Private Sub open_project_data(ByVal filename As String)
        Dim fs As FileStream = New FileStream(filename, FileMode.Open)
        Dim r As StreamReader = New StreamReader(fs)
        Dim inp_fname As String

        Dim out_fname As String
        Try
            'first clear all variables
            reset_all_variables()
            prj_type.prj_main_module = r.ReadLine()
            prj_type.prob_type = r.ReadLine()
            prj_type.comp_type = r.ReadLine()
            'after project type read, initialize the frm_variables
            initialize_frm_variables(Me.prj_type)
            inp_fname = LSet(filename, Len(filename) - 3) & "inp"
            Me.open_input_data(inp_fname)
            With obj_state
```

```
            obj_state.st_intake_des = r.ReadLine()
            obj_state.st_splw_Q = r.ReadLine()
            obj_state.st_energy_dissp = r.ReadLine()
            obj_state.st_riprap_des = r.ReadLine()
            obj_state.st_flush_des = r.ReadLine()
            obj_state.st_seepage_des = r.ReadLine()
            obj_state.st_int_uplift = r.ReadLine()
            obj_state.st_splw_uplift = r.ReadLine()
            obj_state.st_slcw_uplift = r.ReadLine()
            obj_state.st_stab_slide_overt = r.ReadLine()
            obj_state.st_stab_sw_splw = r.ReadLine()
            obj_state.st_stab_sw_slcw = r.ReadLine()
            obj_state.st_levees_des = r.ReadLine()
            obj_state.st_div_fac = r.ReadLine()
            obj_state.st_costs = r.ReadLine()
            obj_state.st_summary_result = r.ReadLine()
            obj_state.st_try_summary_results = r.ReadLine()
            obj_state.st_try_summary_results_OK = r.ReadLine()
         End With
         out_fname = LSet(filename, Len(filename) - 3) & "out"
         Me.open_output_data(out_fname)
         prj_type.prj_title = r.ReadLine
         prj_type.prj_eng = r.ReadLine
         prj_type.prj_date = r.ReadLine
         prj_type.prj_def = r.ReadToEnd 'should be at last in order to handle new line chars
         Me.prj_path = filename
      Catch ex As Exception
         MsgBox(ex.Message & ex.StackTrace)
         'MsgBox("An error occured while opening file." & Chr(13) & "Please check if it is a valid project
file.", MsgBoxStyle.Exclamation, "WINDWEIR")
         Me.prj_path = ""
      Finally
         r.Close()
         fs.Close()
      End Try

   End Sub
   Private Sub open_output_data(ByVal filename As String)
      Dim formatter As New BinaryFormatter()
      Dim stream As New FileStream(filename, FileMode.Open)
      Do Until stream.Position = stream.Length
         With obj_state
            If .st_intake_des Then frm_main.intake_des = CType(formatter.Deserialize(stream), intake)
            If .st_splw_Q Then frm_main.splw_Q = CType(formatter.Deserialize(stream), splw_slcw_Q)
            If .st_energy_dissp Then frm_main.energy_dissp = CType(formatter.Deserialize(stream),
energy_dissp)
            If .st_riprap_des Then frm_main.riprap_des = CType(formatter.Deserialize(stream), riprap_des)
            If .st_flush_des Then frm_main.flush_des = CType(formatter.Deserialize(stream), flushing_canal)
            If .st_seepage_des Then frm_main.seepage_des = CType(formatter.Deserialize(stream),
seepage_analysis)
            If .st_int_uplift Then frm_main.int_uplift = CType(formatter.Deserialize(stream), stab_uplift_sb)
            If .st_splw_uplift Then frm_main.splw_uplift = CType(formatter.Deserialize(stream),
stab_uplift_sb)
            If .st_slcw_uplift Then frm_main.slcw_uplift = CType(formatter.Deserialize(stream),
stab_uplift_sb)
            If .st_stab_slide_overt Then frm_main.stab_slide_overt = CType(formatter.Deserialize(stream),
stab_sliding_and_overt)
            If .st_stab_sw_splw Then frm_main.stab_sw_splw = CType(formatter.Deserialize(stream),
stab_sidewalls)
```

```
            If .st_stab_sw_slcw Then frm_main.stab_sw_slcw = CType(formatter.Deserialize(stream),
stab_sidewalls)
            If .st_levees_des Then frm_main.levees_des = CType(formatter.Deserialize(stream), levees)
            If .st_div_fac Then frm_main.div_fac = CType(formatter.Deserialize(stream), diversion_fac)
            If .st_costs Then frm_main.costs = CType(formatter.Deserialize(stream), costs)
            If .st_summary_result Then frm_main.summary_result = CType(formatter.Deserialize(stream),
optimization_try_output_data)
            If .st_try_summary_results Then frm_main.try_summary_results =
CType(formatter.Deserialize(stream), optimization_try_output_data())
            If .st_try_summary_results_OK Then frm_main.try_summary_results_OK =
CType(formatter.Deserialize(stream), optimization_try_output_data())
          End With
        Loop
        stream.Close()
    End Sub
    Private Sub open_input_data(ByVal filename As String)
        'this code is not well structured; needs to be modified
        frm_inputc.dset_input.Clear()
        frm_inputc.dset_input.ReadXml(filename)
        load_input_data_to_controls()
        'reread the dataset; because the dataset is distorted because of radio_button initializations (found el or slab
thickness)
        'therefore after uploading data to controls, initial dataset must be reread to display the contents of
datagrids correctly
        frm_inputc.dset_input.Clear()
        frm_inputc.dset_input.ReadXml(filename)
        'only for div fac discharge it must be read at last
        frm_inputc.ComboBox4.SelectedIndex =
CInt(frm_inputc.dtbln_combo.Rows.Find(frm_inputc.ComboBox4.Name).Item(1))
    End Sub
    Private Sub load_input_data_to_controls()
        Dim c As Control
        Dim c2 As Control
        Dim text_b As TextBox
        Dim combo_b As ComboBox
        Dim check_b As CheckBox
        Dim radio_b As RadioButton
        Dim tab_page As TabPage
        Dim group_b As GroupBox
        With frm_inputc
            For Each tab_page In frm_inputc.tab_input.TabPages
                For Each c2 In tab_page.Controls
                    If TypeOf (c2) Is GroupBox Then
                        group_b = CType(c2, GroupBox)
                        For Each c In group_b.Controls
                            If TypeOf (c) Is TextBox Then
                                text_b = CType(c, TextBox)
                                text_b.Text = .dtbl_textbox.Rows.Find(text_b.Name).Item(1)
                            ElseIf TypeOf (c) Is ComboBox Then
                                combo_b = CType(c, ComboBox)
                                combo_b.Text = .dtbln_combo.Rows.Find(combo_b.Name).Item(1)
                            ElseIf TypeOf (c) Is CheckBox Then
                                check_b = CType(c, CheckBox)
                                check_b.Checked = .dtbln_checkbox.Rows.Find(check_b.Name).Item(1)
                            ElseIf TypeOf (c) Is RadioButton Then
                                radio_b = CType(c, RadioButton)
                                radio_b.Checked = .dtbln_radio.Rows.Find(radio_b.Name).Item(1)
                            End If
                        Next
                    ElseIf TypeOf (c2) Is TextBox Then
                        text_b = CType(c2, TextBox)
```

```
                    text_b.Text = .dtbl_textbox.Rows.Find(text_b.Name).Item(1)
                ElseIf TypeOf (c2) Is ComboBox Then
                    combo_b = CType(c2, ComboBox)
                    combo_b.Text = .dtbln_combo.Rows.Find(combo_b.Name).Item(1)
                ElseIf TypeOf (c2) Is CheckBox Then
                    check_b = CType(c2, CheckBox)
                    check_b.Checked = .dtbln_checkbox.Rows.Find(check_b.Name).Item(1)
                ElseIf TypeOf (c2) Is RadioButton Then
                    radio_b = CType(c2, RadioButton)
                    radio_b.Checked = .dtbln_radio.Rows.Find(radio_b.Name).Item(1)
                End If
            Next
        Next
    End With
End Sub
#End Region
#Region "save project procedure"
Private Sub save_project()
    If Me.prj_path = "" Then  'if project was not saved before
        Dim save_diag As New SaveFileDialog()
        With save_diag
            .InitialDirectory = Application.ExecutablePath
            .DefaultExt = "dwr"
            .FileName = "project1"
            .Filter = "DWR Files" & " (*.dwr)|*.dwr|All Files (*.*)|*.*"
            .OverwritePrompt = True
            If .ShowDialog = DialogResult.OK Then
                Me.save_project_data(.FileName)
            End If
        End With
    Else  'if project was saved before
        Me.save_project_data(prj_path)
    End If
    Me.StatusBarPanel2.Text = "Project Title:  " & prj_type.prj_title
    Me.StatusBarPanel3.Text = "Project File:  " & prj_path
End Sub
Private Sub save_as_project()
    Dim save_diag As New SaveFileDialog()
    With save_diag
        .InitialDirectory = Application.ExecutablePath
        .DefaultExt = "dwr"
        .FileName = "project1"
        .Filter = "DWR Files" & " (*.dwr)|*.dwr|All Files (*.*)|*.*"
        .OverwritePrompt = True
        If .ShowDialog = DialogResult.OK Then
            Me.save_project_data(.FileName)
        End If
    End With
    Me.StatusBarPanel2.Text = "Project Title:  " & prj_type.prj_title
    Me.StatusBarPanel3.Text = "Project File:  " & prj_path
End Sub
'save the classes; serialize...
Private Sub save_output_data(ByVal filename As String)
    Dim formatter As New BinaryFormatter()
    Dim stream As New FileStream(filename, FileMode.Create)
    Dim i As Integer
    With obj_state
        If (.st_intake_des) Then formatter.Serialize(stream, intake_des)
        If (.st_splw_Q) Then formatter.Serialize(stream, splw_Q)
        If (.st_energy_dissp) Then formatter.Serialize(stream, energy_dissp)
        If (.st_riprap_des) Then formatter.Serialize(stream, riprap_des)
```

```
            If (.st_flush_des) Then formatter.Serialize(stream, flush_des)
            If (.st_seepage_des) Then formatter.Serialize(stream, seepage_des)
            If (.st_int_uplift) Then formatter.Serialize(stream, int_uplift)
            If (.st_splw_uplift) Then formatter.Serialize(stream, splw_uplift)
            If (.st_slcw_uplift) Then formatter.Serialize(stream, slcw_uplift)
            If (.st_stab_slide_overt) Then formatter.Serialize(stream, stab_slide_overt)
            If (.st_stab_sw_splw) Then formatter.Serialize(stream, stab_sw_splw)
            If (.st_stab_sw_slcw) Then formatter.Serialize(stream, stab_sw_slcw)
            If (.st_levees_des) Then formatter.Serialize(stream, levees_des)
            If (.st_div_fac) Then formatter.Serialize(stream, div_fac)
            If (.st_costs) Then formatter.Serialize(stream, costs)
            If (.st_summary_result) Then formatter.Serialize(stream, summary_result)
            If (.st_try_summary_results) Then formatter.Serialize(stream, try_summary_results)
            If (.st_try_summary_results_OK) Then formatter.Serialize(stream, try_summary_results_OK)
        End With
        stream.Close()
    End Sub
    Private Sub save_project_data(ByVal filename As String)
        Dim fs As FileStream = New FileStream(filename, FileMode.Create)
        Dim w As StreamWriter = New StreamWriter(fs)
        Dim inp_fname As String
        Dim out_fname As String
        w.WriteLine(prj_type.prj_main_module)
        w.WriteLine(prj_type.prob_type)
        w.WriteLine(prj_type.comp_type)
        inp_fname = LSet(filename, Len(filename) - 3) & "inp"
        Me.save_input_data(inp_fname)
        out_fname = LSet(filename, Len(filename) - 3) & "out"
        Me.save_output_data(out_fname)
        'write the core objects state
        w.WriteLine(obj_state.st_intake_des)
        w.WriteLine(obj_state.st_splw_Q)
        w.WriteLine(obj_state.st_energy_dissp)
        w.WriteLine(obj_state.st_riprap_des)
        w.WriteLine(obj_state.st_flush_des)
        w.WriteLine(obj_state.st_seepage_des)
        w.WriteLine(obj_state.st_int_uplift)
        w.WriteLine(obj_state.st_splw_uplift)
        w.WriteLine(obj_state.st_slcw_uplift)
        w.WriteLine(obj_state.st_stab_slide_overt)
        w.WriteLine(obj_state.st_stab_sw_splw)
        w.WriteLine(obj_state.st_stab_sw_slcw)
        w.WriteLine(obj_state.st_levees_des)
        w.WriteLine(obj_state.st_div_fac)
        w.WriteLine(obj_state.st_costs)
        w.WriteLine(obj_state.st_summary_result)
        w.WriteLine(obj_state.st_try_summary_results)
        w.WriteLine(obj_state.st_try_summary_results_OK)
        w.WriteLine(prj_type.prj_title)
        w.WriteLine(prj_type.prj_eng)
        w.WriteLine(prj_type.prj_date)
        w.WriteLine(prj_type.prj_def) 'should be at last in order to handle new line chars
        Me.prj_path = filename
        w.Close()
        fs.Close()
    End Sub
    Private Sub save_input_data(ByVal filename As String)
        'not well structured; needs to be modified
        Dim c As Control
        Dim c2 As Control
        Dim text_b As TextBox
```

```
Dim combo_b As ComboBox
Dim check_b As CheckBox
Dim radio_b As RadioButton
Dim tab_page As TabPage
Dim group_b As GroupBox
Dim drow As DataRow
With frm_inputc
    .dtbl_textbox.Clear()
    .dtbln_combo.Clear()
    .dtbln_checkbox.Clear()
    .dtbln_radio.Clear()
    For Each tab_page In frm_inputc.tab_input.TabPages
        For Each c2 In tab_page.Controls
            If TypeOf (c2) Is GroupBox Then
                group_b = CType(c2, GroupBox)
                For Each c In group_b.Controls
                    If TypeOf (c) Is TextBox Then
                        text_b = CType(c, TextBox)
                        drow = .dtbl_textbox.NewRow
                        drow(0) = text_b.Name
                        drow(1) = text_b.Text
                        .dtbl_textbox.Rows.Add(drow)
                    ElseIf TypeOf (c) Is ComboBox Then
                        combo_b = CType(c, ComboBox)
                        drow = .dtbln_combo.NewRow
                        drow(0) = combo_b.Name
                        drow(1) = combo_b.Text
                        .dtbln_combo.Rows.Add(drow)
                    ElseIf TypeOf (c) Is CheckBox Then
                        check_b = CType(c, CheckBox)
                        drow = .dtbln_checkbox.NewRow
                        drow(0) = check_b.Name
                        drow(1) = check_b.Checked
                        .dtbln_checkbox.Rows.Add(drow)
                    ElseIf TypeOf (c) Is RadioButton Then
                        radio_b = CType(c, RadioButton)
                        drow = .dtbln_radio.NewRow
                        drow(0) = radio_b.Name
                        drow(1) = radio_b.Checked
                        .dtbln_radio.Rows.Add(drow)
                    End If
                Next
            ElseIf TypeOf (c2) Is TextBox Then
                text_b = CType(c2, TextBox)
                drow = .dtbl_textbox.NewRow
                drow(0) = text_b.Name
                drow(1) = text_b.Text
                .dtbl_textbox.Rows.Add(drow)
            ElseIf TypeOf (c2) Is ComboBox Then
                combo_b = CType(c, ComboBox)
                drow = .dtbln_combo.NewRow
                drow(0) = combo_b.Name
                drow(1) = combo_b.Text
                .dtbln_combo.Rows.Add(drow)
            ElseIf TypeOf (c2) Is CheckBox Then
                check_b = CType(c2, CheckBox)
                drow = .dtbln_checkbox.NewRow
                drow(0) = check_b.Name
                drow(1) = check_b.Checked
                .dtbln_checkbox.Rows.Add(drow)
            ElseIf TypeOf (c2) Is RadioButton Then
```

```
                radio_b = CType(c2, RadioButton)
                drow = .dtbln_radio.NewRow
                drow(0) = radio_b.Name
                drow(1) = radio_b.Checked
                .dtbln_radio.Rows.Add(drow)
            End If
        Next
    Next
    'for only div fac discharge data seperate access needed
    .dtbln_combo.Rows.Find(.ComboBox4.Name).Item(1) = CStr(.ComboBox4.SelectedIndex)
    .dset_input.WriteXml(filename)
  End With
 End Sub
#End Region
#Region "delete project"
 Private Sub delete_project()
  Dim open_diag As New OpenFileDialog()
  Dim inp_fname As String
  Dim out_fname As String
  Dim msg_info As String = ""
  With open_diag
    .InitialDirectory = Application.ExecutablePath
    .DefaultExt = "dwr"
    .FileName = "project1"
    .Filter = "DWR Files" & " (*.dwr)|*.dwr"
    If .ShowDialog = DialogResult.OK Then
        Kill(.FileName)
        msg_info = "'" & .FileName & "' was deleted..." & Chr(13)
        inp_fname = LSet(.FileName, Len(.FileName) - 3) & "inp"
        out_fname = LSet(.FileName, Len(.FileName) - 3) & "out"
        If File.Exists(inp_fname) Then
            Kill(inp_fname)
            msg_info &= "'" & inp_fname & "' was deleted..." & Chr(13)
        End If
        If File.Exists(out_fname) Then
            Kill(out_fname)
            msg_info &= "'" & out_fname & "' was deleted..." & Chr(13)
        End If
    End If
    MsgBox(msg_info, MsgBoxStyle.Information, "Delete Project")
  End With
 End Sub
#End Region
 Public Shared Sub grid_load(ByVal dtbl As DataTable, ByVal num As Integer, ByVal name As String)
  Dim i As Integer
  Dim drow As DataRow
  For i = 0 To num - 1
    drow = dtbl.NewRow
    drow(0) = name & i + 1
    dtbl.Rows.Add(drow)
  Next
 End Sub
#End Region
 Private Sub MenuItem28_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem28.Click
  frm_inputc.Show()
  frm_inputc.tab_input.SelectedIndex = 8
 End Sub
 Private Sub MenuItem22_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem22.Click
  frm_inputc.Show()
```

```
        frm_inputc.tab_input.SelectedIndex = 2
    End Sub
    Private Sub MenuItem21_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem21.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 1
    End Sub
    Private Sub MenuItem2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem2.Click
        Me.new_project()
    End Sub
    Private Sub MenuItem7_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem7.Click
        Me.open_project()
    End Sub
    Private Sub MenuItem9_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem9.Click
        Me.save_project()
    End Sub
    Private Sub MenuItem10_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem10.Click
        Me.save_as_project()
    End Sub
    Private Sub MenuItem12_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem12.Click
        frm_prj_summaryc = New frm_prj_summary()
        frm_prj_summaryc.Show()
    End Sub
    Private Sub MenuItem29_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem29.Click
        frm_computec = New frm_compute()
        frm_computec.ShowDialog()
    End Sub
    Private Sub MenuItem18_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem18.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 6
    End Sub
    Private Sub MenuItem31_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem31.Click
        Me.output_tables_index = 1
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem32_Click_1(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles MenuItem32.Click
        Me.output_tables_index = 2
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem30_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem30.Click
        Me.output_tables_index = 0
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem24_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem24.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 3
    End Sub
```

```
    Private Sub MenuItem25_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem25.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 5
    End Sub
    Private Sub MenuItem26_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem26.Click
        frm_inputc.Show()
        frm_inputc.tab_input.SelectedIndex = 4
    End Sub
    Private Sub MenuItem33_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem33.Click
        Me.output_tables_index = 3
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem38_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem38.Click
        Dim frm_aboutc As New frm_about()
        frm_aboutc.ShowDialog()
    End Sub
    Private Sub MenuItem39_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem39.Click
        Me.delete_project()
    End Sub
    Private Sub ToolBar1_ButtonClick(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.ToolBarButtonClickEventArgs) Handles ToolBar1.ButtonClick
        Select Case Me.ToolBar1.Buttons.IndexOf(e.Button)
            Case 0 'new project
                Me.new_project()
            Case 1  'open project
                Me.open_project()
            Case 2  'save project
                Me.save_project()
        End Select
    End Sub
    Private Sub MenuItem35_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem35.Click
        Me.output_tables_index = 5
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem37_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem37.Click
        Me.output_tables_index = 7
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem36_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem36.Click
        Me.output_tables_index = 6
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub frm_main_DragDrop(ByVal sender As Object, ByVal e As
System.Windows.Forms.DragEventArgs) Handles MyBase.DragDrop
        Dim x() As String = e.Data.GetData(System.Windows.Forms.DataFormats.FileDrop)
        Me.open_project_data(x(0))
        Me.StatusBarPanel2.Text = "Project Title:" & prj_type.prj_title
        Me.StatusBarPanel3.Text = "Project File:" & prj_path
    End Sub
```

```
    Private Sub frm_main_DragEnter(ByVal sender As Object, ByVal e As
System.Windows.Forms.DragEventArgs) Handles MyBase.DragEnter
        If e.Data.GetDataPresent(DataFormats.FileDrop) Then
            e.Effect = DragDropEffects.All
        Else
            e.Effect = DragDropEffects.None
        End If
    End Sub
    Private Sub MenuItem34_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem34.Click
        Me.output_tables_index = 4
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem41_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem41.Click
        Me.output_tables_index = 9
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub MenuItem42_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem42.Click
        Me.output_tables_index = 8
        Me.frm_out_intc = New frm_outputs()
        Me.frm_out_intc.Show()
    End Sub
    Private Sub StatusBar1_MouseMove(ByVal sender As Object, ByVal e As
System.Windows.Forms.MouseEventArgs) Handles StatusBar1.MouseMove
        Me.StatusBarPanel3.ToolTipText = Me.StatusBarPanel3.Text
    End Sub
    Private Sub frm_main_Closed(ByVal sender As Object, ByVal e As System.EventArgs) Handles
MyBase.Closed
        End
    End Sub
End Class
'*-------------------------------------------------------------------------------------------------------------*
'|                                   END OF FORM-13                                                           |
'*-------------------------------------------------------------------------------------------------------------*
```

```
'*-------------------------------------------------------------------------------------------------------------*
'|                                   FORM-2 : Form2.vb                                                        |
'*-------------------------------------------------------------------------------------------------------------*
Imports dweir_code.General_Hydraulic_Functions
Public Class frm_input
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
```

```
      MyBase.Dispose(disposing)
   End Sub
'Required by the Windows Form Designer
   Private components As System.ComponentModel.IContainer
   'NOTE: The following procedure is required by the Windows Form Designer
   'It can be modified using the Windows Form Designer.
   'Do not modify it using the code editor.
‘This part of code is generated automatically.Details are hidden.
#End Region
   Public changed_vmax As Boolean = False
   Public changed_vmin As Boolean = False
   Private Sub chk_bridge_CheckedChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles chk_bridge.CheckedChanged
      'unenable the bridge data if not checked
      Dim lbl As Label
      Dim ctrl As Control
      For Each ctrl In Me.gbox_bridge.Controls
         If ctrl.Enabled = True And (Not (TypeOf (ctrl) Is Label)) Then
            ctrl.Text = "" 'set to zero if unenabled
         End If
         ctrl.Enabled = Me.chk_bridge.Checked
      Next
      If Not chk_bridge.Checked Then
         If Me.PictureBox4.Image Is Me.PictureBox8.Image Then
            Me.PictureBox4.Image = Me.PictureBox9.Image
         Else
            Me.PictureBox4.Image = Me.PictureBox11.Image
         End If
      Else
         If Me.PictureBox4.Image Is Me.PictureBox9.Image Then
            Me.PictureBox4.Image = Me.PictureBox8.Image
         Else
            Me.PictureBox4.Image = Me.PictureBox10.Image
         End If
      End If
      Me.PictureBox4.Refresh()
   End Sub
   Private Sub comb_Kp_SelectedIndexChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles comb_Kp.SelectedIndexChanged
      With comb_Kp
         Select Case .SelectedIndex
            Case 1
               .Items.Item(0) = "0.02"
            Case 2
               .Items.Item(0) = "0.01"
            Case 3
               .Items.Item(0) = "0"
         End Select
         .SelectedItem = .Items.Item(0)
      End With
   End Sub
   Private Sub comb_Ka_SelectedIndexChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles comb_Ka.SelectedIndexChanged
      With comb_Ka
         Select Case .SelectedIndex
            Case 1
               .Items.Item(0) = "0.2"
            Case 2
               .Items.Item(0) = "0.1"
            Case 3
               .Items.Item(0) = "0"
```

```
            End Select
            .SelectedItem = .Items.Item(0)
        End With
    End Sub
    Private Sub frm_input_Load(ByVal sender As Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        'intake
        frm_main.grid_load(Me.dtbl_intake_l, 5, "L-")
        Me.RadioButton2_CheckedChanged(sender, e)
        'splw
        frm_main.grid_load(Me.dtbl_spl_l, 5, "L-")
        Me.RadioButton4_CheckedChanged(sender, e)
        'initialize some pictureboxes
        Me.PictureBox4.Image = Me.PictureBox8.Image
        Me.PictureBox1.Image = Me.PictureBox14.Image
        Me.PictureBox3.Image = Me.PictureBox12.Image
    End Sub
    Private Sub tab_input_SelectedIndexChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles tab_input.SelectedIndexChanged
        If tab_input.SelectedIndex = 7 Then
            If changed_vmax = False Then TextBox68.Text = Math.Min(Val(ComboBox2.Text) / 1.3,
Val(TextBox52.Text))
            If changed_vmin = False Then TextBox69.Text = (-0.05) * Val(TextBox52.Text)
        End If
    End Sub
    Private Sub TextBox69_KeyDown(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.KeyEventArgs)
        changed_vmin = True
    End Sub
    Private Sub TextBox68_KeyDown(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.KeyEventArgs)
        changed_vmax = True
    End Sub
    Protected Overrides Sub OnClosing(ByVal e As System.ComponentModel.CancelEventArgs)
        'closed prevented, if cancel=true demeseydik; once hide edip sonra kapatacakti
        e.Cancel = True
        Me.Hide()
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        Me.load_input_data()
        Me.load_input_data_structures()
    End Sub
    'GUI procedures when changing input type slab thickness or elevations
    Private Sub RadioButton2_CheckedChanged(ByVal sender As Object, ByVal e As System.EventArgs)
Handles RadioButton2.CheckedChanged
        'by lear method we delete data (but not the table schema)
        'if we also want to delete table shema; then refresh method is used)
        If Me.RadioButton1.Checked = False Then
            Me.DataGrid3.CaptionText = "Foundation El : (refer to figure)"
            Me.dtbl_spl_el.Clear()
            Me.dtbl_spl_el.Columns.Item(1).ColumnName = "Elevation (m.)"
            frm_main.grid_load(Me.dtbl_spl_el, 7, "El-")
            Me.PictureBox3.Image = Me.PictureBox13.Image
        Else
            Me.DataGrid3.CaptionText = "Slab thicknesses : (refer to figure)"
            Me.dtbl_spl_el.Clear()
            Me.dtbl_spl_el.Columns.Item(1).ColumnName = "Thickness (m.)"
            frm_main.grid_load(Me.dtbl_spl_el, 7, "t-")
            Me.PictureBox3.Image = Me.PictureBox12.Image
        End If
```

```
        Me.PictureBox3.Refresh()
    End Sub
    Private Sub RadioButton4_CheckedChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles RadioButton4.CheckedChanged
        If Me.RadioButton3.Checked = False Then
            Me.dg_intake_el.CaptionText = "Foundation El : (refer to figure)"
            Me.dtbl_intake_el.Clear()
            Me.dtbl_intake_el.Columns.Item(1).ColumnName = "Elevation (m.)"
            frm_main.grid_load(Me.dtbl_intake_el, 7, "El-")
            Me.PictureBox1.Image = Me.PictureBox15.Image
        Else
            Me.dg_intake_el.CaptionText = "Slab thicknesses : (refer to figure)"
            Me.dtbl_intake_el.Clear()
            Me.dtbl_intake_el.Columns.Item(1).ColumnName = "Thickness (m.)"
            frm_main.grid_load(Me.dtbl_intake_el, 7, "t-")
            Me.PictureBox1.Image = Me.PictureBox14.Image
        End If
        Me.PictureBox1.Refresh()
    End Sub
#Region "my procedures"
    Private Sub load_input_data()
        Dim i As Integer = 0
        Dim frm As frm_main
        With frm
            'initialize the array type variables
            If Me.dtbl_Q_flood.Rows.Count <> 0 Then
                ReDim .Q(Me.dtbl_Q_flood.Rows.Count - 1)
                ReDim .Kd(Me.dtbl_Q_flood.Rows.Count - 1)
                ReDim .profile(Me.dtbl_Q_flood.Rows.Count - 1)
                For i = 0 To Me.dtbl_Q_flood.Rows.Count - 1
                    .profile(i) = Me.dtbl_Q_flood.Rows(i).Item(0)
                    .Q(i) = Me.dtbl_Q_flood.Rows(i).Item(1)
                    .Kd(i) = Me.dtbl_Q_flood.Rows(i).Item(2)
                Next
            End If
            If Me.dtbl_intake_l.Rows.Count <> 0 Then
                ReDim .L_int(Me.dtbl_intake_l.Rows.Count - 1)
                For i = 0 To Me.dtbl_intake_l.Rows.Count - 1
                    .L_int(i) = Me.dtbl_intake_l.Rows(i).Item(1)
                Next
            End If
            If Me.dtbl_intake_el.Rows.Count <> 0 Then
                ReDim .El_int(Me.dtbl_intake_el.Rows.Count - 1)
                For i = 0 To Me.dtbl_intake_el.Rows.Count - 1
                    .El_int(i) = Me.dtbl_intake_el.Rows(i).Item(1)
                Next
            End If
            .dim_int_by_El = Me.RadioButton2.Checked 'gets if dims by found el or slab thickness
            If Me.dtbl_spl_el.Rows.Count <> 0 Then
                ReDim .L_spl(Me.dtbl_spl_l.Rows.Count - 1)
                For i = 0 To Me.dtbl_spl_l.Rows.Count - 1
                    .L_spl(i) = Me.dtbl_spl_l.Rows(i).Item(1)
                Next
            End If
            If Me.dtbl_spl_el.Rows.Count <> 0 Then
                ReDim .El_spl(Me.dtbl_spl_el.Rows.Count - 1)
                For i = 0 To Me.dtbl_spl_el.Rows.Count - 1
                    .El_spl(i) = Me.dtbl_spl_el.Rows(i).Item(1)
                Next
            End If
            .dim_splw_by_El = Me.RadioButton4.Checked 'gets if dims by found el or slab thickness
```

```
.Qirr = Val(Me.tb_Qirr.Text)
.So_main = Val(Me.tb_So_main.Text)
.B_main = Val(Me.tb_B_main.Text)
.K1 = Val(Me.tb_K1.Text)
.n_conc = Val(Me.tb_n_conc.Text)
.mh_main = Val(Me.tb_mh_main.Text)
.n_river = Val(Me.tb_n_river.Text)
.Kt = Val(Me.TextBox48.Text)
.Kr = Val(Me.TextBox49.Text)
.So_river = Val(Me.TextBox92.Text)
.C = Val(Me.ComboBox3.Text)
.Sac = Val(Me.TextBox52.Text)
.Saf = Val(Me.ComboBox2.Text)
.f = Val(Me.ComboBox1.Text)
.Tall = Val(Me.TextBox53.Text)
.Fi = Val(Me.TextBox56.Text)
.kh = Val(Me.TextBox54.Text)
.kv = Val(Me.TextBox55.Text)
.gconc = Val(Me.TextBox50.Text)
.gwater = Val(Me.TextBox51.Text)
.teta = Val(Me.TextBox75.Text)
.gdry = Val(Me.TextBox74.Text)
.gsat = Val(Me.TextBox73.Text)
.Lc = Val(Me.TextBox84.Text)
.L23 = Val(Me.TextBox85.Text)
.np = Val(Me.TextBox4.Text)
.tp = Val(Me.TextBox5.Text)
.tg = 0.5  'default olarak 10 cm al, kullaniciyi bu detayla mesgul etme
.Lp = Val(Me.TextBox86.Text)
.npi = Val(Me.TextBox12.Text)
.tpi = Val(Me.TextBox13.Text)
.tgi = 0.5  'default olarak 10 cm al, kullaniciyi bu detayla mesgul etme
.Lpi = Val(Me.TextBox87.Text)
.tr = Val(Me.TextBox15.Text)
.Df = Val(Me.TextBox16.Text)
.Sd = Val(Me.TextBox9.Text)
.Dm = Val(Me.TextBox10.Text)
.r = Val(Me.TextBox11.Text)
.Ct = Val(Me.TextBox1.Text)
.Cc = Val(Me.TextBox2.Text)
.u5 = Val(Me.TextBox17.Text)
.Lub_int = Val(Me.TextBox79.Text)
.Hsp_int = Val(Me.TextBox78.Text)
.Dsu = Val(Me.TextBox7.Text)
.maxDsu = Val(Me.TextBox18.Text)
.Dsd = Val(Me.TextBox8.Text)
.maxDu = Val(Me.TextBox19.Text)
.minDu = Val(Me.TextBox20.Text)
.dim_int_by_El = Me.RadioButton4.Checked
.Lt = Val(Me.TextBox24.Text)
.nsl = Val(Me.TextBox25.Text)
.Le = Val(Me.TextBox26.Text)
.d = Val(Me.TextBox27.Text)
.tsl = Val(Me.TextBox80.Text)
.Lp_slcw = Val(Me.TextBox90.Text)
.tg_slcw = 0.5  'default olarak 10 cm al, kullaniciyi bu detayla mesgul etme
.dim_int_by_El = Me.RadioButton2.Checked
.brdg_exist = Me.chk_bridge.Checked
.np_brdg = Val(Me.tb_Np.Text)
.tp_brdg = Val(Me.tb_tp.Text)
.Kp = Val(Me.comb_Kp.Text)
```

```
        .Ka = Val(Me.comb_Ka.Text)
        .Lp_brdg = Val(Me.TextBox82.Text)
        .tslab_brdg = Val(Me.TextBox3.Text)
        .wslab_brdg = Val(Me.TextBox83.Text)
        .coulomb_type = False 'default; we eliminated the coulomb type in our program
        .sw_comp_type = IIf(Me.CheckBox2.Checked, 1, 0)
        .tc_sw = Val(Me.TextBox31.Text)
        .tslab_sw = Val(Me.TextBox30.Text)
        .tb_sw = Val(Me.TextBox88.Text)
        .B_sw = Val(Me.TextBox28.Text)
        .gwd_sw = Val(Me.TextBox29.Text)
        .z_levee = Val(Me.TextBox32.Text)
        .dx_levee = Val(Me.TextBox33.Text)
        .tc_splw_auto = Me.CheckBox1.Checked
        .tc_splw = Val(Me.TextBox81.Text)

        .mh_spl = Val(Me.TextBox21.Text)
        .Lub_spl = Val(Me.TextBox22.Text)
        .Hsp_spl = Val(Me.TextBox23.Text)
        .Ldc = Val(Me.TextBox34.Text)
        .mh_div = Val(Me.TextBox35.Text)
        .Kta = Val(Me.TextBox36.Text)
        If Me.ComboBox4.Items.Count <> 0 Then
            .Qdiv = Me.dtbl_Q_flood.Rows(Me.ComboBox4.SelectedIndex).Item(1)
        End If
        .Ktb = Val(Me.TextBox38.Text)
        .Kb = Val(Me.TextBox40.Text)
        .delta_div = Val(Me.TextBox41.Text)
        .dx_div = Val(Me.TextBox37.Text)
        .mh_uc = Val(Me.TextBox46.Text)
        .mh_dc = Val(Me.TextBox47.Text)
        .uCe = Val(Me.TextBox45.Text)
        .uCl = Val(Me.TextBox44.Text)
        .uCex = Val(Me.TextBox43.Text)
        .uCcore = Val(Me.TextBox42.Text)
        .uCper = Val(Me.TextBox39.Text)
        .t_ripmin = Val(Me.TextBox57.Text)
        .Ld_ripmin = Val(Me.TextBox58.Text)
        .Dm_flush = Val(Me.TextBox59.Text)
        .Dp_flush = Val(Me.TextBox60.Text)
        .ks_flush = Val(Me.TextBox77.Text)
        .n_flush = Val(Me.TextBox76.Text)
        .alfa_flush = Val(Me.TextBox61.Text)
        .FSu = Val(Me.TextBox63.Text)
        .FSs = Val(Me.TextBox64.Text)
        .FSss = Val(Me.TextBox65.Text)
        .FSo = Val(Me.TextBox66.Text)
        .FSs_sw = Val(Me.TextBox67.Text)
        .Vmax = Val(Me.TextBox68.Text)
        .Vmin = Val(Me.TextBox69.Text)
        .uCco = Val(Me.TextBox70.Text)
        .uCcs = Val(Me.TextBox71.Text)
        .uCrip = Val(Me.TextBox72.Text)
    End With
End Sub
Private Sub load_input_data_structures()
    Dim frm As frm_main
    'intake input
    With frm.inp_intake
        .Qi = frm.Qirr
        .So = frm.So_main
```

```
    .Bop = frm.B_main
    .K0 = frm.K1
    .n = frm.n_conc
    .B1 = 2 * .Bop  'when recalculated; these must reentered also
    .B1_inc = 0.01
    .Bs = 10 '.B1 + 1   'when recalculated; these must reentered also
    .Bs_inc = 0.01
    .Cc = frm.Cc
    .Ct = frm.Ct
    .Cyc = 1.1
    .delta_Kwi = 0.1
    .Dfo = frm.Df
    .dHes = 0.02
    .Dm = frm.Dm
    .dsd = frm.Dsd
    .dsd_inc = 0.01
    .dsu = frm.Dsu
    .dsu_inc = 0.01
    .dsu_max = frm.maxDsu
    .du_max = frm.maxDu
    .du_min = frm.minDu
    .hl_add = 0
    .K = 0.65
    .Kst = frm.Kt
    .Kv = 0.42
    .Ls = 0 'no need
    .Ls_inc = 2
    .L12 = frm.L23
    .Lc = frm.Lc
    .Lentr = frm.L_int(0) + frm.L_int(1) + frm.L_int(2)
    .mh = frm.mh_main
    .n_tr = 0 'no need
    .np = frm.np
    .np2 = frm.npi
    .r = frm.r
    .Sd = frm.Sd
    .t = frm.tp

    .t2 = frm.tpi
    .t_tr = frm.tr
    .u4_max = frm.u5
End With
'splw and sluiceway Q input data
With frm.inp_Q_splw_slcw
    .bridge_exist = frm.brdg_exist
    .d = frm.d
    .Ka = frm.Ka
    .Kd = frm.Kd
    .Kp = frm.Kp
    .Kr = frm.Kr
    .Kst = frm.Kt
    .Le = frm.Le
    .Lt = frm.Lt
    .mh_s = 0 'vertical spillway
    .np = frm.np_brdg
    .tp = frm.tp_brdg
    .nsl = frm.nsl
    .Q = frm.Q
    .profile = frm.profile
    .tsl = frm.tsl
End With
```

```
'energy dissipator
With frm.inp_energy_dissp
    .profile = frm.profile
    .Kd = frm.Kd
    .Kr = frm.Kr
    .Kst = frm.Kt
    .Le = frm.Le
    .Lt = frm.Lt
    .n_aprch = frm.n_river 'no need
    .nsl = frm.nsl
    .tsl = frm.tsl
End With
'intake geom input data
With frm.inp_int_geom
    'for the time being no need to fill this data str(it is done at comp)
End With
'splw geom input data
With frm.inp_splw_geom
    'for the time being no need to fill this data str(it is done at comp)
End With
'slcw geom input data
With frm.inp_slcw_geom
    'for the time being no need to fill this data str(it is done at comp)
End With
'sidewalls_splw input data
With frm.inp_sw_splw
    .change_dim_type = frm_main.sw_comp_type
    .coulomb_type = frm_main.coulomb_type
    .gwd = frm_main.gwd_sw
    .mh_free = 0
    .q_surch = 0
    .t1 = frm_main.tslab_sw
    .t2 = 0
    .tc = frm_main.tc_sw
    .tc_base = frm_main.tb_sw
    .t3 = frm_main.B_sw - .t2 - .tc_base
End With
'sidewalls_slcw input data
frm.inp_sw_slcw = frm.inp_sw_splw
'material data
With frm.inp_mtrl
    .Cac = frm.Sac
    .Caf = frm.Saf
    .Callw = 0 'for the time being no need
    .f = frm.f
    .gconc = frm.gconc
    .gdry = frm.gdry
    .gsat = frm.gsat
    .gwater = frm.gwater
    .kh = frm.kh
    .kv = frm.kv
    .Sallw_cf = frm.Tall
    .teta = frm.teta
    .ured_perc = 1 - frm.Fi
End With
'FS data
With frm.inp_FS
    .FSo = frm.FSo
    .FSs = frm.FSs
    .FSss = frm.FSss
    .Fsu = frm.FSu
```

```
            .FSo_sw = 1.0 'we don't consider overturning only consider sliding
            .FSs_sw = frm.FSs_sw
            .Vmax = frm.Vmax
            .Vmin = frm.Vmin
            .Vmax_sw = frm.Vmax
            .Vmin_sw = frm.Vmin
        End With
        'unit costs input data
        With frm.inp_unit_costs
            .uCcore = frm.uCcore
            .uCe = frm.uCe
            .uCex = frm.uCex
            .uCl = frm.uCl
            .uCper = frm.uCper
        End With
        'diversion fac input_data
        With frm.inp_div
            .delta_s = frm.delta_div
            .dx = frm.dx_div
            .Kb = frm.Kb
            .Kta = frm.Kta
            .Ktb = frm.Ktb
            .Ldc = frm.Ldc
            .Lt = frm.Lt
            .mh = frm.mh_div
            .mh_d = frm.mh_dc
            .mh_u = frm.mh_uc
            .n = frm.n_conc
            .Q = frm.Qdiv
            If Me.ComboBox4.Items.Count <> 0 Then
                .profile_name = frm.profile(Me.ComboBox4.SelectedIndex)
            End If
        End With
        'cost calculations input_data
        With frm.inp_cost_comp
            .Lp = frm.Lp
            .Lp2 = frm.Lpi
            .Lp_bridge = frm.Lp_brdg
            .Lp_slcw = frm.Lp_slcw
            .t_blanket = 0.3
            .t_sheet = 0.3
            .tg = frm.tg
            .tg2 = frm.tgi
            .tg_slcw = frm.tg_slcw
            .tslab = 0.1  'trap/rect canal slab width
            .tslab_bridge = frm.tslab_brdg
            .twall = 0.1    'trap/rect canal wall width
            .width_bridge = frm.wslab_brdg
            .width_tr = frm.tr
            .uC_conc = frm.uCco
            .uC_riprap = frm.uCrip
            .uC_steel = frm.uCcs
        End With
    End Sub
#End Region
    Private Sub ComboBox3_SelectedIndexChanged_1(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ComboBox3.SelectedIndexChanged
        With ComboBox3
            Select Case .SelectedIndex
                Case 1
                    .Items.Item(0) = "8.5"
```

```
            Case 2
                .Items.Item(0) = "7.0"
            Case 3
                .Items.Item(0) = "6.0"
            Case 4
                .Items.Item(0) = "5.0"
            Case 5
                .Items.Item(0) = "4.0"
            Case 6
                .Items.Item(0) = "3.5"
            Case 7
                .Items.Item(0) = "3.0"
            Case 8
                .Items.Item(0) = "2.5"
            Case 9
                .Items.Item(0) = "2.0"
            Case 10
                .Items.Item(0) = "1.8"
            Case 11
                .Items.Item(0) = "1.6"
        End Select
        .SelectedItem = .Items.Item(0)
    End With
End Sub
Private Sub ComboBox1_SelectedIndexChanged_1(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ComboBox1.SelectedIndexChanged
    With ComboBox1
        Select Case .SelectedIndex
            Case 1
                .Items.Item(0) = "0.8"
            Case 2
                .Items.Item(0) = "0.7"
            Case 3
                .Items.Item(0) = "0.4"
            Case 4
                .Items.Item(0) = "0.3"
            Case 5
                .Items.Item(0) = "0.3"
        End Select
        .SelectedItem = .Items.Item(0)
    End With
End Sub
Private Sub ComboBox2_SelectedIndexChanged_1(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ComboBox2.SelectedIndexChanged
    With ComboBox2
        Select Case .SelectedIndex
            Case 1
                .Items.Item(0) = "5000"
            Case 2
                .Items.Item(0) = "3750"
            Case 3
                .Items.Item(0) = "3250"
            Case 4
                .Items.Item(0) = "375"
            Case 5
                .Items.Item(0) = "275"
            Case 6
                .Items.Item(0) = "275"
            Case 7
                .Items.Item(0) = "75"
        End Select
```

```
            .SelectedItem = .Items.Item(0)
        End With
    End Sub
    'after changed...
    Private Sub CheckBox1_CheckedChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles CheckBox1.CheckedChanged
        Me.Label88.Enabled = Not CheckBox1.Checked
        Me.TextBox81.Enabled = Not CheckBox1.Checked
        Me.Label26.Enabled = CheckBox1.Checked
        Me.TextBox21.Enabled = CheckBox1.Checked
        If Me.TextBox81.Enabled = False Then
            Me.TextBox81.Text = "0" 'remember in the computation class od spillway; if tc=0 crest thickness
calculated automatically
        End If
        If Me.TextBox21.Enabled = False Then
            Me.TextBox21.Text = "0" 'remember in the computation class od spillway; if tc=0 crest thickness
calculated automatically
        End If
    End Sub
    Private Sub gbox_bridge_Enter(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
gbox_bridge.Enter
    End Sub
    Private Sub LinkLabel1_LinkClicked(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.LinkLabelLinkClickedEventArgs) Handles LinkLabel1.LinkClicked
        If Me.chk_bridge.Checked Then
            Me.PictureBox4.Image = Me.PictureBox8.Image
        Else
            Me.PictureBox4.Image = Me.PictureBox9.Image
        End If
        Me.PictureBox4.Refresh()
    End Sub
    Private Sub LinkLabel2_LinkClicked(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.LinkLabelLinkClickedEventArgs) Handles LinkLabel2.LinkClicked
        If Me.chk_bridge.Checked Then
            Me.PictureBox4.Image = Me.PictureBox10.Image
        Else
            Me.PictureBox4.Image = Me.PictureBox11.Image
        End If
        Me.PictureBox4.Refresh()
    End Sub
End Class
'*------------------------------------------------------------------------------------------------------------------------------------*
'|                                        END OF FORM-2                                                                               |
'*------------------------------------------------------------------------------------------------------------------------------------*


'*------------------------------------------------------------------------------------------------------------------------------------*
'|                                        FORM-3 : Form3.vb                                                                           |
'*------------------------------------------------------------------------------------------------------------------------------------*
Imports dweir_code.General_Hydraulic_Functions
Imports dweir_code.General_Hydraulic_Functions.OCH_func
Imports dweir_code.intake_design
Imports dweir_code.splw_slcw_design
Imports dweir_code.stability_analysis
Imports dweir_code.Appurtenant_fac
Imports dweir_code.levees_and_diversion
Imports dweir_code.cost_computations
Imports dweir_code.computations
Public Class frm_compute
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
```

```
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
    'This part of code is generated automatically. Details are hidden.
#End Region
    Public thr As Threading.Thread
    Private whole_dweir As whole_dweir
    Private optimize_whole_dweir As optimize_Bmain
    Private frm_comp As frm_comp_process
    Private inp_whole_dweir As New dweir_input_data()
    Private comp_inf_list As New Queue()
    Private Sub frm_compute_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        Me.load_prj_inf()
    End Sub
#Region "my procedures"
    Private Sub load_prj_inf()
        Dim i As Integer
        If Me.ListView1.Items(0).SubItems.Count = 1 Then 'eger bir tanesi varsa hepsi de vardir mantigi..
            For i = 0 To 5
                Me.ListView1.Items(i).SubItems.Add("")
            Next
        End If
        With frm_main.prj_type
            Me.ListView1.Items(0).SubItems(1).Text = .prj_title
            Me.ListView1.Items(1).SubItems(1).Text = IIf(.prj_main_module, "Main Module", "Secondary
Module")
            Select Case .prob_type
                Case 0
                    Me.ListView1.Items(2).SubItems(1).Text = "Diversion Weir with Overflow Spillway"
                Case 1
                    Me.ListView1.Items(2).SubItems(1).Text = "Gated Diversion Weir"
                Case 2 'tirol type in future
            End Select
            Select Case .comp_type
                Case 0 'normal
                    Me.ListView1.Items(3).SubItems(1).Text = "Normal Computation"
                Case 1 'optimization wrt to Bmain
                    Me.ListView1.Items(3).SubItems(1).Text = "Optimization of bottom width at the beginning of
irrigation canal"
                Case 2
            End Select
            Me.ListView1.Items(4).SubItems(1).Text = .prj_eng
            Me.ListView1.Items(5).SubItems(1).Text = .prj_date
```

```
        Me.TextBox1.Text = .prj_def
    End With
End Sub
Private Sub load_whole_dweir_input()
    With inp_whole_dweir
        .alfa_int = frm_main.alfa_flush
        .C = frm_main.C
        .dim_int_by_El = frm_main.dim_int_by_El
        .dim_splw_by_El = frm_main.dim_splw_by_El
        .Dm_flush = frm_main.Dm_flush
        .Dp_flush = frm_main.Dp_flush
        .dx_levees = frm_main.dx_levee
        .El_int = frm_main.El_int
        .El_spl = frm_main.El_spl
        .Hsp_int = frm_main.Hsp_int
        .Hsp_spl = frm_main.Hsp_spl
        .input_diversion = frm_main.inp_div
        .input_dweir_cost = frm_main.inp_cost_comp
        .input_energy_dissipators = frm_main.inp_energy_dissp
        .input_Fs = frm_main.inp_FS
        .input_geom_intake = frm_main.inp_int_geom
        .input_geom_slcw = frm_main.inp_slcw_geom
        .input_geom_splw = frm_main.inp_splw_geom
        .input_intake = frm_main.inp_intake
        .input_mtrl = frm_main.inp_mtrl
        .input_Q_splw_slcw = frm_main.inp_Q_splw_slcw
        .input_sidewalls_slcw = frm_main.inp_sw_slcw
        .input_sidewalls_splw = frm_main.inp_sw_splw
        .input_uCosts = frm_main.inp_unit_costs
        .ks_flush = frm_main.ks_flush
        .L_int = frm_main.L_int
        .L_spl = frm_main.L_spl
        .Ld_min = frm_main.Ld_ripmin
        .Lub_int = frm_main.Lub_int
        .Lub_spl = frm_main.Lub_spl
        .min_riprap_height = frm_main.t_ripmin
        .n_flush = frm_main.n_flush
        .n_river = frm_main.n_river
        .So_river = frm_main.So_river
        .tc_splw = frm_main.tc_splw
        .mh_ogee = frm_main.mh_spl
        .crest_auto = frm_main.tc_splw_auto
        .z_levees = frm_main.z_levee
    End With
End Sub
Private Sub load_final_input_data_struct_for_comp()
    With frm_main.prj_type
        If .prj_main_module = True Then 'main module ise
            If .prob_type = 0 Then 'overflow Dweir
                Me.load_whole_dweir_input()
            ElseIf .prob_type = 1 Then 'gated type

                'Will be added in the future...
            Else 'other; tirol type
                'Will be added in the future...
            End If
        Else 'secondary module
            'Will be added in the future...

        End If
    End With
```

```
        Me.comp_inf_list.Enqueue(f_comp_inf(10, " Input Data loaded successfully", 0))
        error_hand.add_inf(Me.comp_inf_list, frm_comp.ListView1, frm_comp.ProgressBar1)
    End Sub
    Private Sub load_results_to_data_structures()
        With frm_main.prj_type
            If .prj_main_module = True Then 'main module ise
                If .prob_type = 0 Then 'overflow Dweir
                    Select Case .comp_type
                        Case 0 'normal exec
                            frm_main.intake_des = whole_dweir.intake_pro
                            frm_main.splw_Q = whole_dweir.Q_splw_slcw_pro
                            frm_main.energy_dissp = whole_dweir.energy_dissipators_pro
                            frm_main.riprap_des = whole_dweir.riprap_pro
                            frm_main.flush_des = whole_dweir.flushing_canal_pro
                            frm_main.seepage_des = whole_dweir.seepage_pro
                            frm_main.int_uplift = whole_dweir.uplift_intake_pro
                            frm_main.splw_uplift = whole_dweir.uplift_splw_pro
                            frm_main.slcw_uplift = whole_dweir.uplift_slcw_pro
                            frm_main.stab_slide_overt = whole_dweir.sliding_overturning_pro
                            frm_main.stab_sw_splw = whole_dweir.sidewalls_splw_pro
                            frm_main.stab_sw_slcw = whole_dweir.sidewalls_slcw_pro
                            frm_main.levees_des = whole_dweir.us_levees_pro
                            frm_main.div_fac = whole_dweir.diversion_fac_pro
                            frm_main.costs = whole_dweir.dweir_cost_pro
                            frm_main.summary_result = whole_dweir.comp_summary_pro
                        Case 1 'optimize Bmain
                            frm_main.intake_des = optimize_whole_dweir.opt_dweir_pro.intake_pro
                            frm_main.splw_Q = optimize_whole_dweir.opt_dweir_pro.Q_splw_slcw_pro
                            frm_main.energy_dissp = optimize_whole_dweir.opt_dweir_pro.energy_dissipators_pro
                            frm_main.riprap_des = optimize_whole_dweir.opt_dweir_pro.riprap_pro
                            frm_main.flush_des = optimize_whole_dweir.opt_dweir_pro.flushing_canal_pro
                            frm_main.seepage_des = optimize_whole_dweir.opt_dweir_pro.seepage_pro
                            frm_main.int_uplift = optimize_whole_dweir.opt_dweir_pro.uplift_intake_pro
                            frm_main.splw_uplift = optimize_whole_dweir.opt_dweir_pro.uplift_splw_pro
                            frm_main.slcw_uplift = optimize_whole_dweir.opt_dweir_pro.uplift_slcw_pro
                            frm_main.stab_slide_overt = optimize_whole_dweir.opt_dweir_pro.sliding_overturning_pro
                            frm_main.stab_sw_splw = optimize_whole_dweir.opt_dweir_pro.sidewalls_splw_pro
                            frm_main.stab_sw_slcw = optimize_whole_dweir.opt_dweir_pro.sidewalls_slcw_pro
                            frm_main.levees_des = optimize_whole_dweir.opt_dweir_pro.us_levees_pro
                            frm_main.div_fac = optimize_whole_dweir.opt_dweir_pro.diversion_fac_pro
                            frm_main.costs = optimize_whole_dweir.opt_dweir_pro.dweir_cost_pro
                            frm_main.summary_result = optimize_whole_dweir.opt_dweir_summarypro
                            'redim the tries
                            Dim i As Integer
                            ReDim
frm_main.try_summary_results(optimize_whole_dweir.dweir_try_pro.GetUpperBound(0))
                            For i = 0 To frm_main.try_summary_results.GetUpperBound(0)
                                frm_main.try_summary_results(i) =
optimize_whole_dweir.dweir_try_pro(i).comp_summary_pro
                            Next
                            ReDim
frm_main.try_summary_results_OK(optimize_whole_dweir.dweir_try_OK_pro.GetUpperBound(0))
                            For i = 0 To frm_main.try_summary_results_OK.GetUpperBound(0)
                                frm_main.try_summary_results_OK(i) =
optimize_whole_dweir.dweir_try_OK_pro(i).comp_summary_pro
                            Next
                    End Select
                ElseIf .prob_type = 1 Then 'gated type
                    'Will be added in the future...
                Else 'other; tirol type
                    'Will be added in the future...
```

```
            End If
        Else 'secondary module
            'Will be added in the future...
        End If
    End With
    load_obj_states()
    Me.comp_inf_list.Enqueue(f_comp_inf(100, " COMPUTATION ENDS", 0))
    error_hand.add_inf(Me.comp_inf_list, frm_comp.ListView1, frm_comp.ProgressBar1)
End Sub
Public Shared Sub load_obj_states()
    'load the objects states
    With frm_main.obj_state
        .st_div_fac = Not IsNothing(frm_main.div_fac)
        .st_energy_dissp = Not IsNothing(frm_main.energy_dissp)
        .st_flush_des = Not IsNothing(frm_main.flush_des)
        .st_int_uplift = Not IsNothing(frm_main.int_uplift)
        .st_intake_des = Not IsNothing(frm_main.intake_des)
        .st_levees_des = Not IsNothing(frm_main.levees_des)
        .st_costs = Not IsNothing(frm_main.costs)
        .st_riprap_des = Not IsNothing(frm_main.riprap_des)
        .st_seepage_des = Not IsNothing(frm_main.seepage_des)
        .st_slcw_uplift = Not IsNothing(frm_main.slcw_uplift)
        .st_splw_Q = Not IsNothing(frm_main.splw_Q)
        .st_splw_uplift = Not IsNothing(frm_main.splw_uplift)
        .st_stab_slide_overt = Not IsNothing(frm_main.stab_slide_overt)
        .st_stab_sw_splw = Not IsNothing(frm_main.stab_sw_splw)
        .st_stab_sw_slcw = Not IsNothing(frm_main.stab_sw_slcw)
        .st_summary_result = Not IsNothing(frm_main.summary_result)
        .st_try_summary_results = Not IsNothing(frm_main.try_summary_results)
        .st_try_summary_results_OK = Not IsNothing(frm_main.try_summary_results_OK)
    End With
End Sub
Private Sub compute()
    'call the compute process form
    Me.comp_inf_list.Enqueue(f_comp_inf(5, " COMPUTATION STARTS", 0))
    error_hand.add_inf(Me.comp_inf_list, frm_comp.ListView1, frm_comp.ProgressBar1)
    Dim i As Integer = 0
    With frm_main.prj_type
        If .prj_main_module = True Then 'main module ise
            If .prob_type = 0 Then 'overflow Dweir
                Me.load_final_input_data_struct_for_comp()
                Select Case .comp_type
                    Case 0 'normal exec
                        whole_dweir = New whole_dweir(inp_whole_dweir, Me.comp_inf_list,
frm_comp.ListView1, frm_comp.ProgressBar1)
                        whole_dweir.compute()
                        load_results_to_data_structures()
                    Case 1 'optimize Bmain
                        optimize_whole_dweir = New optimize_Bmain(inp_whole_dweir, Me.comp_inf_list,
frm_comp.ListView1, frm_comp.ProgressBar1)
                        optimize_whole_dweir.compute()
                        load_results_to_data_structures()
                End Select
            ElseIf .prob_type = 1 Then 'gated type
                'Will be added in the future...
            Else 'other; tirol type
                'Will be added in the future...
            End If
        Else 'secondary module
            'Will be added in the future...
        End If
```

```
        End With
        frm_comp.Button1.Text = "CLOSE"
    End Sub
#End Region
    'only one radio button is necessary, one click , others unclicked
    Private Sub RadioButton1_CheckedChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles RadioButton1.CheckedChanged
        If Me.RadioButton1.Checked = True Then
            frm_main.prj_type.comp_type = 0 'normal exec
        ElseIf Me.RadioButton2.Checked = True Then
            frm_main.prj_type.comp_type = 1 'optimize Bmain
        End If
        Me.load_prj_inf()
    End Sub
    Private Sub RadioButton2_CheckedChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles RadioButton2.CheckedChanged
        Me.load_prj_inf()
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        'always start from 0 (zero) in all our logic
        If Me.RadioButton1.Checked = True Then
            frm_main.prj_type.comp_type = 0 'normal exec
        ElseIf Me.RadioButton2.Checked = True Then
            frm_main.prj_type.comp_type = 1 'optimize Bmain
        End If
        thr = New Threading.Thread(AddressOf compute)
        Me.Hide()
        frm_comp = New frm_comp_process()
        thr.Start()
        frm_comp.ShowDialog()
        'thr.IsBackground = True
        '
    End Sub
End Class
'*-----------------------------------------------------------------------------------------------------------------------*
'|                                    END OF FORM-3                                                                       |
'*-----------------------------------------------------------------------------------------------------------------------*


'*-----------------------------------------------------------------------------------------------------------------------*
'|                                    FORM-8 : Form8.vb                                                                   |
'*-----------------------------------------------------------------------------------------------------------------------*
Public Class frm_comp_process
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
```

```
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
   ‘This part of code is generated automatically. Details are hidden.
#End Region
    Private Sub frm_comp_process_Load(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles MyBase.Load
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        If Me.Button1.Text = "STOP  COMPUTATION" Then
            frm_main.frm_computec.thr.Suspend()
            Me.Button1.Text = "RESUME COMPUTATION"

        ElseIf Me.Button1.Text = "RESUME COMPUTATION" Then
            Me.Button1.Text = "STOP COMPUTATION"
            frm_main.frm_computec.thr.Resume()
        ElseIf Me.Button1.Text = "CLOSE" Then
            Me.Dispose()
        End If
    End Sub
    Private Sub frm_comp_process_Closed(ByVal sender As Object, ByVal e As System.EventArgs) Handles
MyBase.Closed
        frm_main.frm_computec.Dispose()
    End Sub
End Class
'*-----------------------------------------------------------------------------------------------------------------------------*
'|                                    END OF FORM-8                                                                            |
'*-----------------------------------------------------------------------------------------------------------------------------*


'*-----------------------------------------------------------------------------------------------------------------------------*
'|                                    FORM-9 : Form9.vb                                                                        |
'*-----------------------------------------------------------------------------------------------------------------------------*
Public Class frm_prj_type
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.

        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
   ‘This part of code is generated automatically. Details are hidden.
```

```
#End Region
    Private Sub ToolBar1_ButtonClick(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.ToolBarButtonClickEventArgs) Handles ToolBar1.ButtonClick
        Me.Button1.Enabled = False 'in order to force the user to select a prj type
        With Me.ListView1
            Select Case Me.ToolBar1.Buttons.IndexOf(e.Button)
                Case 0  'main modules
                    Me.ToolBarButton1.Pushed = True
                    Me.ToolBarButton2.Pushed = False
                    load_list_view(True)
                    frm_main.prj_type.prj_main_module = True
                Case 1   'secondary modules
                    Me.ToolBarButton1.Pushed = False
                    Me.ToolBarButton2.Pushed = True
                    load_list_view(False)
                    frm_main.prj_type.prj_main_module = False
            End Select
        End With
    End Sub
    Private Sub load_list_view(ByVal main_module As Boolean)
        With Me.ListView1
            .Clear()
            If main_module = True Then
                .Items.Add("Diversion Weir with Overflow Spillway", 0)
                ' .Items.Add("Gated Diversion Weir", 1) to be added in the future
            Else
                .Items.Add("Intake Hydraulics", 2)
                .Items.Add("Discharges and Energy Dissipators", 3)
                .Items.Add("Seepage Analysis", 4)
                .Items.Add("Intake Stability Analysis against Uplift", 5)
                .Items.Add("Spillway Body+Apron Stability Analysis", 6)
                .Items.Add("Sidewalls", 7)
                .Items.Add("Upstream Levees", 8
                                .Items.Add("Riprap Design", 9)
                .Items.Add("Flushing Canal", 10)
                .Items.Add("Diversion Facility", 11)
            End If
        End With
    End Sub
    Private Sub frm_prj_type_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        'default is the main_module
        load_list_view(True)
        frm_main.prj_type.prj_main_module = True
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button1.Click
        frm_main.prj_type.prob_type = Me.ListView1.FocusedItem.Index
        Me.Dispose()
    End Sub
    Private Sub ListView1_DoubleClick(ByVal sender As Object, ByVal e As System.EventArgs) Handles
ListView1.DoubleClick
        frm_main.prj_type.prob_type = Me.ListView1.FocusedItem.Index
        Me.Dispose()
    End Sub
    Private Sub ListView1_SelectedIndexChanged(ByVal sender As System.Object, ByVal e As
System.EventArgs) Handles ListView1.SelectedIndexChanged
        Me.Button1.Enabled = True
    End Sub
    Private Sub Button2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
Button2.Click
```

```
    End Sub
End Class
'*----------------------------------------------------------------------------------------------------------------------------*
'|                                    END OF FORM-9                                                                            |
'*----------------------------------------------------------------------------------------------------------------------------*


'*----------------------------------------------------------------------------------------------------------------------------*
'|                                    FORM-4 : Form4.vb                                                                        |
'*----------------------------------------------------------------------------------------------------------------------------*
mports System.Math
Imports CustomControls
Public Class frm_outputs
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
    'Do not modify it using the code editor.
    ‘This part of code is generated automaticallt. Details are hidden.
#End Region
    Public Shared chart_no As Integer 'in order to access to charts (all charts not ordered, from 0 to ....)
    Private Sub frm_output_int_Load(ByVal sender As System.Object, ByVal e As System.EventArgs)
Handles MyBase.Load
        Select Case frm_main.output_tables_index
            Case 0 'intake
                Me.load_intake_tables()
            Case 1 'spillway_slcw Q
                Me.load_splw_slcw_Q_tables()
            Case 2
                Me.load_seepage_tables()
            Case 3
                Me.load_stab_analy_tables()
            Case 4 'sidewalls
                Me.load_sw_tables()
            Case 5
                Me.load_levees_tables()
            Case 6 'div fac
                Me.load_div_fac_tables()
            Case 7 'appert fac
                Me.load_app_fac_tables()
            Case 8 'cost
                Me.load_cost_tables()
            Case 9 'optimization summary
                Me.load_opt_Bmain_tables()
```

```
        End Select
    End Sub
#Region "my procedures"
#Region "intake tables"
    Private Sub load_intake_tables()
        Me.ToolBarButton2.DropDownMenu = Me.mnu_int_tables
        Me.ToolBarButton3.DropDownMenu = Me.mnu_int_graphs
        'check if object is loaded (referenced)
        If IsNothing(frm_main.intake_des) = False Then
            Me.load_int_out()
            Me.load_int_out2()
        End If
        Me.GroupBox1.Text = "Outputs of the Intake computations"
        'show the default table
        Me.DataGridEx2.CaptionText = "Intake Water Surface Profile Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_int)
        Me.DataGridEx2.DataSource = Me.dtbln_out_int
    End Sub
    Private Sub load_int_out()
    End Sub
#End Region
#Region "spillway and sluiceway discharge and energy dissipators table"
    Private Sub load_splw_slcw_Q_tables()
        Me.ToolBarButton2.DropDownMenu = Me.mnu_splw_slcw_Q_tables
        Me.ToolBarButton3.DropDownMenu = Me.mnu_splw_slcw_Q_graphs
        'check if object is loaded (referenced)
        If IsNothing(frm_main.splw_Q) = False Then
            Me.load_splw_slcw_Q_out()
        End If
        If IsNothing(frm_main.energy_dissp) = False Then
            Me.load_energy_dissp_out()
        End If
        Me.GroupBox1.Text = "Outputs of the Spillway-Sluiceway discharge computations and corresponding
energy dissipators"
        'show the default table
        Me.DataGridEx2.CaptionText = "Spillway - Sluiceway Discharge Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_splw_slcw)
        Me.DataGridEx2.DataSource = Me.dtbln_out_splw_slcw
    End Sub
    Private Sub load_splw_slcw_Q_out()
    End Sub
    Private Sub load_energy_dissp_out()
    End Sub
#End Region
#Region "Seepage analysis tables"
    Private Sub load_seepage_tables()
        Me.ToolBarButton2.DropDownMenu = Me.mnu_seepage
        Me.ToolBarButton3.DropDownMenu = Me.mnu_seepage_graphs
        'check if object is loaded (referenced)
        If IsNothing(frm_main.seepage_des) = False Then
            Me.load_seepage_out()
        End If
        Me.GroupBox1.Text = "Outputs of the Seepage computations"
        'show the default table
        Me.DataGridEx2.CaptionText = "Seepage Computations Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_seepage)
        Me.DataGridEx2.DataSource = Me.dtbln_out_seepage
    End Sub
    Private Sub load_seepage_out()
        Dim i As Integer
        Dim x As DataRow
```

```
    With frm_main.seepage_des
      'values
      For i = 0 To .inp_K_pro.GetUpperBound(0) + 4 '+3 for columns; description, symbols and units, full
u/s no tailwater case
        Me.dtbln_out_seepage.Columns.Add(i + 1, Type.GetType("System.String"))
      Next
      For i = 0 To Me.dtbln_out_seepage.Columns.Count - 1
        Me.dtbln_out_seepage.Columns(i).DefaultValue = ""
      Next
      'insert output data
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "MAX NET HEAD TABLE"
      Me.dtbln_out_seepage.Rows.Add(x)
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "Description"
      x(1) = "Symbols"
      x(2) = "Units"
      Me.dtbln_out_seepage.Rows.Add(x)
      'cases
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "Flow case"
      x(1) = ""
      x(2) = ""
      For i = 0 To .inp_K_pro.GetUpperBound(0)
        x(i + 3) = "Overflowing"
      Next
      x(i + 3) = "Full u/s no tailwater"
      Me.dtbln_out_seepage.Rows.Add(x)
      'flow profile
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "Flow Profile"
      x(1) = ""
      x(2) = ""
      For i = 0 To .inp_K_pro.GetUpperBound(0)
        x(i + 3) = .profile_pro(i)
      Next
      Me.dtbln_out_seepage.Rows.Add(x)
      'Ku
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "upstream water surface elevation"
      x(1) = "Ku"
      x(2) = "(m.)"
      For i = 0 To .inp_K_pro.GetUpperBound(0)
        x(i + 3) = .inp_K_pro(i)
      Next
      Me.dtbln_out_seepage.Rows.Add(x)
      'Kd
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "tailwater water surface elevation"
      x(1) = "Kd"
      x(2) = "(m.)"
      For i = 0 To .inp_K_pro.GetUpperBound(0)
        x(i + 3) = .inp_Kd_pro(i)
      Next
      Me.dtbln_out_seepage.Rows.Add(x)
      'Ks
      x = Me.dtbln_out_seepage.NewRow
      x(0) = "crest elev. of spillway"
      x(1) = "Ks"
      x(2) = "(m.)"
      x(Me.dtbln_out_seepage.Columns.Count - 1) = .inp_Ks_pro
```

```
Me.dtbln_out_seepage.Rows.Add(x)
'Kr
x = Me.dtbln_out_seepage.NewRow
x(0) = "tailwater bottom elevation"
x(1) = "Kr"
x(2) = "(m.)"
x(Me.dtbln_out_seepage.Columns.Count - 1) = .inp_Kr_pro
Me.dtbln_out_seepage.Rows.Add(x)
'H
x = Me.dtbln_out_seepage.NewRow
x(0) = "net head"
x(1) = "H"
x(2) = "(m.)"
For i = 0 To .inp_K_pro.GetUpperBound(0)
    x(i + 3) = .H_overf_pro(i)
Next
x(Me.dtbln_out_seepage.Columns.Count - 1) = .H_funtw_pro
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
Me.dtbln_out_seepage.Rows.Add(x)
'seepage path table
x = Me.dtbln_out_seepage.NewRow
x(0) = "SEEPAGE PATH TABLE"
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
x(0) = "Description"
x(1) = "X-coordinate"
x(2) = "Y-coordinate"
x(3) = "creep length"
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
x(0) = "Symbols"
x(1) = "x"
x(2) = "y"
x(3) = "ELx"
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
x(0) = "Units"
x(1) = "(m.)"
x(2) = "(m.)"
x(3) = "(m.)"
Me.dtbln_out_seepage.Rows.Add(x)
For i = 0 To .inp_creep_path_pro.GetUpperBound(0)
    x = Me.dtbln_out_seepage.NewRow
    x(0) = "Point-" & i + 1
    x(1) = .inp_creep_path_pro(i).x
    x(2) = .inp_creep_path_pro(i).y
    x(3) = .ELx_pro(i)
    Me.dtbln_out_seepage.Rows.Add(x)
Next
x = Me.dtbln_out_seepage.NewRow
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
Me.dtbln_out_seepage.Rows.Add(x)
'summary
x = Me.dtbln_out_seepage.NewRow
x(0) = "SUMMARY OF THE RESULTS"
Me.dtbln_out_seepage.Rows.Add(x)
x = Me.dtbln_out_seepage.NewRow
```

```
            x(0) = "Description"
            x(1) = "Symbols"
            x(2) = "Units"
            Me.dtbln_out_seepage.Rows.Add(x)
            'max Hnet
            x = Me.dtbln_out_seepage.NewRow
            x(0) = "max net head"
            x(1) = "Hnet_max"
            x(2) = "(m.)"
            x(3) = .Hnet_pro
            Me.dtbln_out_seepage.Rows.Add(x)
            'C
            x = Me.dtbln_out_seepage.NewRow
            x(0) = "relative permeability"
            x(1) = "C"
            x(2) = ""
            x(3) = .inp_C_pro
            Me.dtbln_out_seepage.Rows.Add(x)
            'CH
            x = Me.dtbln_out_seepage.NewRow
            x(0) = "min. required creep length for no piping"
            x(1) = "C*H"
            x(2) = "(m.)"
            x(3) = .CH_pro
            Me.dtbln_out_seepage.Rows.Add(x)
            'Lcr
            x = Me.dtbln_out_seepage.NewRow
            x(0) = "calculated creep length"
            x(1) = "Lcr"
            x(2) = "(m.)"
            x(3) = .Lcr_pro
            Me.dtbln_out_seepage.Rows.Add(x)
            'satisfactory
            x = Me.dtbln_out_seepage.NewRow
            x(0) = "Satisfactory"
            x(1) = "Lcr > C*H"
            x(2) = ""
            x(3) = IIf(.satisfactory_pro, "OK", "not OK")
            Me.dtbln_out_seepage.Rows.Add(x)
        End With
    End Sub
#End Region
#Region "Stability Analysis tables"
    Private Sub load_stab_analy_tables()
        Me.ToolBarButton2.DropDownMenu = Me.mnu_stab
        Me.ToolBarButton3.DropDownMenu = Nothing 'no graph
        'check if object is loaded (referenced)
        If Not IsNothing(frm_main.int_uplift) Then
            Me.load_stab_uplift_int_out()
        End If
        If Not IsNothing(frm_main.splw_uplift) Then
            Me.load_stab_uplift_splw_out()
        End If
        If Not IsNothing(frm_main.slcw_uplift) Then
            Me.load_stab_uplift_slcw_out()
        End If
        If Not IsNothing(frm_main.stab_slide_overt) Then
            Me.load_stab_sliding_out()
            Me.load_stab_overt_out_funt()
            Me.load_stab_overt_out_er_wrt_toe()
            Me.load_stab_overt_out_er_wrt_heel()
```

```
    End If
    Me.GroupBox1.Text = "Outputs of the Stability Analysis"
    'show the default table
    Me.DataGridEx2.CaptionText = "Intake Stability against Uplift Results Table:"
    Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_upl_int)
    Me.DataGridEx2.DataSource = Me.dtbln_out_stab_upl_int
End Sub
Private Sub load_stab_uplift_int_out()
    Dim i As Integer
    Dim x As DataRow
    With frm_main.int_uplift
        'create columns
        For i = 0 To 6
            Me.dtbln_out_stab_upl_int.Columns.Add(i + 1, Type.GetType("System.String"))
        Next
        For i = 0 To Me.dtbln_out_stab_upl_int.Columns.Count - 1
            Me.dtbln_out_stab_upl_int.Columns(i).DefaultValue = ""
        Next
        'insert output data
        'seepage table
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "SEEPAGE TABLE"
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        'headers
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "Description"
        x(1) = "X-coordinate"
        x(2) = "Y-coordinate"
        x(3) = "Creep length"
        x(4) = "head loss"
        x(5) = "Static head"
        x(6) = "uplift pressure"
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        'symbols
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "Symbols"
        x(1) = "X"
        x(2) = "Y"
        x(3) = "ELx"
        x(4) = "hx"
        x(5) = "H"
        x(6) = "ux"
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        'units
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "Units"
        x(1) = "(m.)"
        x(2) = "(m.)"
        x(3) = "(m.)"
        x(4) = "(m.)"
        x(5) = "(m.)"
        x(6) = "(m.)"
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        'values
        For i = 0 To .input_geom_pro.creep_path.GetUpperBound(0)
            x = Me.dtbln_out_stab_upl_int.NewRow
            x(0) = "Point-" & i + 1
            x(1) = .input_geom_pro.creep_path(i).x
            x(2) = .input_geom_pro.creep_path(i).y
            x(3) = .ELx_pro(i)
            x(4) = .hx_pro(i)
```

```
    x(5) = .shead_pro(i)
    x(6) = .ux_pro(i)
    Me.dtbln_out_stab_upl_int.Rows.Add(x)
Next
x = Me.dtbln_out_stab_upl_int.NewRow
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'summary of the results
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "RESULTS OF SEEPAGE CALCULATION"
Me.dtbln_out_stab_upl_int.Rows.Add(x)
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'ELx
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "Total creep length"
x(1) = "ELx"
x(2) = "(m.)"
x(3) = .Lcr_pro
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'Hnet
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "Net head"
x(1) = "H"
x(2) = "(m.)"
x(3) = .Hnet_pro
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'head loss per unit length
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "head loss per unit length"
x(1) = "H / ELx"
x(2) = ""
x(3) = .hl_per_Lx_pro
Me.dtbln_out_stab_upl_int.Rows.Add(x)
x = Me.dtbln_out_stab_upl_int.NewRow
Me.dtbln_out_stab_upl_int.Rows.Add(x)
x = Me.dtbln_out_stab_upl_int.NewRow
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'Stability table
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "UPLIFT STABILITY TABLE"
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'headers
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'Wa
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "weight of basin"
x(1) = "Wa"
x(2) = "(kN/m)"
x(3) = .Wa_pro
Me.dtbln_out_stab_upl_int.Rows.Add(x)
'Fu
x = Me.dtbln_out_stab_upl_int.NewRow
x(0) = "Uplift force"
x(1) = "Fu"
```

```
        x(2) = "(kN/m)"
        x(3) = .Fu_pro
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        'drains add
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "drains added"
        x(1) = ""
        x(2) = ""
        x(3) = IIf(.drains_add_pro, "YES", "NO")
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        If .drains_add_pro Then
            'drains add
            x = Me.dtbln_out_stab_upl_int.NewRow
            x(0) = "uplift reduction coeff"
            x(1) = "Fi"
            x(2) = ""
            x(3) = 1 - .inp_ured_perc_pro
            Me.dtbln_out_stab_upl_int.Rows.Add(x)
            'Fu_final
            x = Me.dtbln_out_stab_upl_int.NewRow
            x(0) = "reduced uplift force"
            x(1) = "Fu_red"
            x(2) = "(kN/m)"
            x(3) = .Fu_final_pro
            Me.dtbln_out_stab_upl_int.Rows.Add(x)
        End If
        'Factor of safety
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "Factor of safety"
        x(1) = "FSu"
        x(2) = ""
        x(3) = .Fsu_final_pro
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
        'Satisfactory
        x = Me.dtbln_out_stab_upl_int.NewRow
        x(0) = "Satisfactory"
        x(1) = IIf(.satisfactory_pro, "FSu >= " & .Fsu_pro, "FSu < " & .Fsu_pro)
        x(2) = ""
        x(3) = IIf(.satisfactory_pro, "OK", "not OK")
        Me.dtbln_out_stab_upl_int.Rows.Add(x)
    End With
End Sub
Private Sub load_stab_uplift_splw_out()
    Dim i As Integer
    Dim x As DataRow
    With frm_main.splw_uplift
        'create columns
        For i = 0 To 6
            Me.dtbln_out_stab_upl_splw.Columns.Add(i + 1, Type.GetType("System.String"))
        Next
        For i = 0 To Me.dtbln_out_stab_upl_splw.Columns.Count - 1
            Me.dtbln_out_stab_upl_splw.Columns(i).DefaultValue = ""
        Next
        'insert output data
        'seepage table
        x = Me.dtbln_out_stab_upl_splw.NewRow
        x(0) = "SEEPAGE TABLE"
        Me.dtbln_out_stab_upl_splw.Rows.Add(x)
        'headers
        x = Me.dtbln_out_stab_upl_splw.NewRow
        x(0) = "Description"
```

```
x(1) = "X-coordinate"
x(2) = "Y-coordinate"
x(3) = "Creep length"
x(4) = "head loss"
x(5) = "Static head"
x(6) = "uplift pressure"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'symbols
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Symbols"
x(1) = "X"
x(2) = "Y"
x(3) = "ELx"
x(4) = "hx"
x(5) = "H"
x(6) = "ux"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'units
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Units"
x(1) = "(m.)"
x(2) = "(m.)"
x(3) = "(m.)"
x(4) = "(m.)"
x(5) = "(m.)"
x(6) = "(m.)"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'values
For i = 0 To .input_geom_pro.creep_path.GetUpperBound(0)
    x = Me.dtbln_out_stab_upl_splw.NewRow
    x(0) = "Point-" & i + 1
    x(1) = .input_geom_pro.creep_path(i).x
    x(2) = .input_geom_pro.creep_path(i).y
    x(3) = .ELx_pro(i)
    x(4) = .hx_pro(i)
    x(5) = .shead_pro(i)
    x(6) = .ux_pro(i)
    Me.dtbln_out_stab_upl_splw.Rows.Add(x)
Next
x = Me.dtbln_out_stab_upl_splw.NewRow
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'summary of the results
'summary of the results
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "RESULTS OF SEEPAGE CALCULATION"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'ELx
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Total creep length"
x(1) = "ELx"
x(2) = "(m.)"
x(3) = .Lcr_pro
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'Hnet
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Net head"
```

```
x(1) = "H"
x(2) = "(m.)"
x(3) = .Hnet_pro
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'head loss per unit length
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "head loss per unit length"
x(1) = "H / ELx"
x(2) = ""
x(3) = .hl_per_Lx_pro
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
x = Me.dtbln_out_stab_upl_splw.NewRow
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
x = Me.dtbln_out_stab_upl_splw.NewRow
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'Stability table
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "UPLIFT STABILITY TABLE"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'headers
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'Wa
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "weight of basin"
x(1) = "Wa"
x(2) = "(kN/m)"
x(3) = .Wa_pro
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'Fu
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "Uplift force"
x(1) = "Fu"
x(2) = "(kN/m)"
x(3) = .Fu_pro
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
'drains add
x = Me.dtbln_out_stab_upl_splw.NewRow
x(0) = "drains added"
x(1) = ""
x(2) = ""
x(3) = IIf(.drains_add_pro, "YES", "NO")
Me.dtbln_out_stab_upl_splw.Rows.Add(x)
If .drains_add_pro Then
  'drains add
  x = Me.dtbln_out_stab_upl_splw.NewRow
  x(0) = "uplift reduction coeff"
  x(1) = "Fi"
  x(2) = ""
  x(3) = 1 - .inp_ured_perc_pro
  Me.dtbln_out_stab_upl_splw.Rows.Add(x)
  'Fu_final
  x = Me.dtbln_out_stab_upl_splw.NewRow
  x(0) = "reduced uplift force"
  x(1) = "Fu_red"
  x(2) = "(kN/m)"
  x(3) = .Fu_final_pro
  Me.dtbln_out_stab_upl_splw.Rows.Add(x)
```

```
        End If
        'Factor of safety
        x = Me.dtbln_out_stab_upl_splw.NewRow
        x(0) = "Factor of safety"
        x(1) = "FSu"
        x(2) = ""
        x(3) = .Fsu_final_pro
        Me.dtbln_out_stab_upl_splw.Rows.Add(x)
        'Satisfactory
        x = Me.dtbln_out_stab_upl_splw.NewRow
        x(0) = "Satisfactory"
        x(1) = IIf(.satisfactory_pro, "FSu >= " & .Fsu_pro, "FSu < " & .Fsu_pro)
        x(2) = ""
        x(3) = IIf(.satisfactory_pro, "OK", "not OK")
        Me.dtbln_out_stab_upl_splw.Rows.Add(x)
    End With
End Sub
Private Sub load_stab_uplift_slcw_out()
    Dim i As Integer
    Dim x As DataRow
    With frm_main.slcw_uplift
        'create columns
        For i = 0 To 6
            Me.dtbln_out_stab_upl_slcw.Columns.Add(i + 1, Type.GetType("System.String"))
        Next
        For i = 0 To Me.dtbln_out_stab_upl_slcw.Columns.Count - 1
            Me.dtbln_out_stab_upl_slcw.Columns(i).DefaultValue = ""
        Next
        'insert output data
        'seepage table
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "SEEPAGE TABLE"
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        'headers
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "Description"
        x(1) = "X-coordinate"
        x(2) = "Y-coordinate"
        x(3) = "Creep length"
        x(4) = "head loss"
        x(5) = "Static head"
        x(6) = "uplift pressure"
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        'symbols
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "Symbols"
        x(1) = "X"
        x(2) = "Y"
        x(3) = "ELx"
        x(4) = "hx"
        x(5) = "H"
        x(6) = "ux"
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        'units
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "Units"
        x(1) = "(m.)"
        x(2) = "(m.)"
        x(3) = "(m.)"
        x(4) = "(m.)"
        x(5) = "(m.)"
```

```
x(6) = "(m.)"
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'values
For i = 0 To .input_geom_pro.creep_path.GetUpperBound(0)
    x = Me.dtbln_out_stab_upl_slcw.NewRow
    x(0) = "Point-" & i + 1
    x(1) = .input_geom_pro.creep_path(i).x
    x(2) = .input_geom_pro.creep_path(i).y
    x(3) = .ELx_pro(i)
    x(4) = .hx_pro(i)
    x(5) = .shead_pro(i)
    x(6) = .ux_pro(i)
    Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
Next
x = Me.dtbln_out_stab_upl_slcw.NewRow
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'summary of the results
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "RESULTS OF SEEPAGE CALCULATION"
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'ELx
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "Total creep length"
x(1) = "ELx"
x(2) = "(m.)"
x(3) = .Lcr_pro
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'Hnet
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "Net head"
x(1) = "H"
x(2) = "(m.)"
x(3) = .Hnet_pro
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'head loss per unit length
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "head loss per unit length"
x(1) = "H / ELx"
x(2) = ""
x(3) = .hl_per_Lx_pro
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
x = Me.dtbln_out_stab_upl_slcw.NewRow
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
x = Me.dtbln_out_stab_upl_slcw.NewRow
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'Stability table
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "UPLIFT STABILITY TABLE"
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'headers
x = Me.dtbln_out_stab_upl_slcw.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
'Wa
```

```
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "weight of basin"
        x(1) = "Wa"
        x(2) = "(kN/m)"
        x(3) = .Wa_pro
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        'Fu
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "Uplift force"
        x(1) = "Fu"
        x(2) = "(kN/m)"
        x(3) = .Fu_pro
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        'drains add
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "drains added"
        x(1) = ""
        x(2) = ""
        x(3) = IIf(.drains_add_pro, "YES", "NO")
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        If .drains_add_pro Then
            'drains add
            x = Me.dtbln_out_stab_upl_slcw.NewRow
            x(0) = "uplift reduction coeff"
            x(1) = "Fi"
            x(2) = ""
            x(3) = 1 - .inp_ured_perc_pro
            Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
            'Fu_final
            x = Me.dtbln_out_stab_upl_slcw.NewRow
            x(0) = "reduced uplift force"
            x(1) = "Fu_red"
            x(2) = "(kN/m)"
            x(3) = .Fu_final_pro
            Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        End If
        'Factor of safety
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "Factor of safety"
        x(1) = "FSu"
        x(2) = ""
        x(3) = .Fsu_final_pro
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
        'Satisfactory
        x = Me.dtbln_out_stab_upl_slcw.NewRow
        x(0) = "Satisfactory"
        x(1) = IIf(.satisfactory_pro, "FSu >= " & .Fsu_pro, "FSu < " & .Fsu_pro)
        x(2) = ""
        x(3) = IIf(.satisfactory_pro, "OK", "not OK")
        Me.dtbln_out_stab_upl_slcw.Rows.Add(x)
    End With
End Sub
Private Sub load_stab_sliding_out()
    Dim i As Integer
    Dim x As DataRow
    With frm_main.stab_slide_overt
        'create columns
        For i = 0 To 6
            Me.dtbln_out_stab_slide_splw.Columns.Add(i + 1, Type.GetType("System.String"))
        Next
        For i = 0 To Me.dtbln_out_stab_slide_splw.Columns.Count - 1
```

```
    Me.dtbln_out_stab_slide_splw.Columns(i).DefaultValue = ""
Next
'insert output data
'seepage table
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "***SEEPAGE TABLE***"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'headers
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Description"
x(1) = "X-coordinate"
x(2) = "Y-coordinate"
x(3) = "Creep length"
x(4) = "head loss"
x(5) = "Static head"
x(6) = "uplift pressure"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'symbols
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Symbols"
x(1) = "X"
x(2) = "Y"
x(3) = "ELx"
x(4) = "hx"
x(5) = "H"
x(6) = "ux"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'units
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Units"
x(1) = "(m.)"
x(2) = "(m.)"
x(3) = "(m.)"
x(4) = "(m.)"
x(5) = "(m.)"
x(6) = "(m.)"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'values
For i = 0 To .input_geom_pro.creep_path.GetUpperBound(0)
    x = Me.dtbln_out_stab_slide_splw.NewRow
    x(0) = "Point-" & i + 1
    x(1) = .input_geom_pro.creep_path(i).x
    x(2) = .input_geom_pro.creep_path(i).y
    x(3) = .ELx_pro(i)
    x(4) = .hx_pro(i)
    x(5) = .shead_pro(i)
    x(6) = .ux_pro(i)
    Me.dtbln_out_stab_slide_splw.Rows.Add(x)
Next
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'summary of the results
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "***RESULTS OF SEEPAGE CALCULATION***"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'ELx
```

```
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Total creep length"
x(1) = "ELx"
x(2) = "(m.)"
x(3) = .Lcr_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Hnet
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Net head"
x(1) = "H"
x(2) = "(m.)"
x(3) = .Hnet_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'head loss per unit length
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "head loss per unit length"
x(1) = "H / ELx"
x(2) = ""
x(3) = .hl_per_Lx_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Stability table
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "***SLIDING STABILITY TABLE***"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'headers
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Description"
x(1) = "Symbols"
x(2) = "Units"
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Vertical forces
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "VERTICAL FORCES"
x(1) = ""
x(2) = ""
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Fu
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Uplift force"
x(1) = "Fu"
x(2) = "(kN/m)"
x(3) = -.Fu_pro  '- is for force coordinate
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'drains add
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "drains added"
x(1) = ""
x(2) = ""
x(3) = IIf(.drains_add_pro, "YES", "NO")
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
If .drains_add_pro Then
   'drains add
   x = Me.dtbln_out_stab_slide_splw.NewRow
   x(0) = "uplift reduction coeff"
   x(1) = "Fi"
   x(2) = ""
   x(3) = 1 - .input_mtrl_pro.ured_perc
```

```
    Me.dtbln_out_stab_slide_splw.Rows.Add(x)
End If
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'crest thickness of spillway
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "crest thickness of spillway"
x(1) = "tc"
x(2) = "(m.)"
x(3) = .tc_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'W dead loads
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Dead loads"
x(1) = "W"
x(2) = "(kN/m)"
x(3) = .W_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'vertical eq forces
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Vertical eq. forces"
x(1) = "Fdv"
x(2) = "(kN/m)"
x(3) = -.Fdv_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'vertical forces total
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Total Vertical forces"
x(1) = "Fv_tot"
x(2) = "(kN/m)"
x(3) = .Ftot_v_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Horizantal forces
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "HORIZANTAL FORCES"
x(1) = ""
x(2) = ""
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Fh
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Hydrostatic force"
x(1) = "Fu"
x(2) = "(kN/m)"
x(3) = .Fu_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Fuh
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Hydrostatic force below u/s blanket"
x(1) = "Fuh"
x(2) = "(kN/m)"
x(3) = .Fuh_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'upstream dyn force
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "u/s dynamic force"
```

```
x(1) = "Fw"
x(2) = "(kN/m)"
x(3) = .Fw_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'lateral earth pressure force Fs
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Lateral active earth press.force"
x(1) = "Fs"
x(2) = "(kN/m)"
x(3) = .Fs_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Horizantal eq force
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Horizantal earthquake force"
x(1) = "Fdh"
x(2) = "(kN/m)"
x(3) = .Fdh_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'total Horizantal  forces
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Total horizantal forces"
x(1) = "Fh_tot"
x(2) = "(kN/m)"
x(3) = .Ftot_h_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Factor of safety against sliding
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "***FACTOR OF SAFETY AGAINST SLIDING***"
x(1) = ""
x(2) = ""
x(3) = ""
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'FSs
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Factor of safety"
x(1) = "FSs"
x(2) = ""
x(3) = .FSs_comp_pro
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Satisfactory
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "Satisfactory"
x(1) = IIf(.OK_s_pro, "FSs >= " & .FSs_pro, "FSs < " & .FSs_pro)
x(2) = ""
x(3) = IIf(.OK_s_pro, "OK", "not OK")
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
x = Me.dtbln_out_stab_slide_splw.NewRow
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Factor of safety against shear and sliding
x = Me.dtbln_out_stab_slide_splw.NewRow
x(0) = "***FACTOR OF SAFETY AGAINST SHEAR&SLIDING***"
x(1) = ""
x(2) = ""
x(3) = ""
Me.dtbln_out_stab_slide_splw.Rows.Add(x)
'Area shear plane
x = Me.dtbln_out_stab_slide_splw.NewRow
```

```
            x(0) = "Area of Shear plane"
            x(1) = "A"
            x(2) = "(m2)"
            x(3) = .Ashear_pro
            Me.dtbln_out_stab_slide_splw.Rows.Add(x)
            'f
            x = Me.dtbln_out_stab_slide_splw.NewRow
            x(0) = "friction coeff."
            x(1) = "f"
            x(2) = ""
            x(3) = .input_mtrl_pro.f
            Me.dtbln_out_stab_slide_splw.Rows.Add(x)
            'allow shear stress in concrete
            x = Me.dtbln_out_stab_slide_splw.NewRow
            x(0) = "allow shear stress in concrete"
            x(1) = "Sallw"
            x(2) = "(kN/m2)"
            x(3) = .input_mtrl_pro.Sallw_cf
            Me.dtbln_out_stab_slide_splw.Rows.Add(x)
            'FSss
            x = Me.dtbln_out_stab_slide_splw.NewRow
            x(0) = "Factor of safety"
            x(1) = "FSss"
            x(2) = ""
            x(3) = .FSss_comp_pro
            Me.dtbln_out_stab_slide_splw.Rows.Add(x)
            'Satisfactory
            x = Me.dtbln_out_stab_slide_splw.NewRow
            x(0) = "Satisfactory"
            x(1) = IIf(.OK_ss_pro, "FSss >= " & .FSss_pro, "FSss < " & .FSss_pro)
            x(2) = ""
            x(3) = IIf(.OK_ss_pro, "OK", "not OK")
            Me.dtbln_out_stab_slide_splw.Rows.Add(x)
        End With
    End Sub
    Private Sub load_stab_overt_out_funt()
    End Sub
#End Region
#Region "appertunant fac"
    Private Sub load_app_fac_tables()
     End Sub
    Private Sub load_riprap_out()
    End Sub
#End Region
#Region "optimization Bmain summary"
    Private Sub load_opt_Bmain_tables()
        Me.ToolBarButton2.DropDownMenu = Me.mnu_opt_Bmain
        Me.ToolBarButton3.DropDownMenu = Me.mnu_opt_Bmain_graphs
        'check if object is loaded (referenced)
        If ((Not IsNothing(frm_main.try_summary_results)) And (Not
IsNothing(frm_main.try_summary_results_OK))) Then
            Me.load_opt_Bmain_out()
        End If
        Me.GroupBox1.Text = "Outputs of the optimization of bottom width of main irrigation canal"
        'show the default table
        Me.DataGridEx2.CaptionText = "Summary of the Optimization Tries Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_opt_Bmain)
        Me.DataGridEx2.DataSource = Me.dtbln_out_opt_Bmain
    End Sub
    Private Sub load_opt_Bmain_out()
        Dim i As Integer
```

```
Dim x As DataRow
With frm_main.try_summary_results
    'create columns
    Me.dtbln_out_opt_Bmain.Columns.Add("1", Type.GetType("System.String"))
    Me.dtbln_out_opt_Bmain.Columns.Add("2", Type.GetType("System.String"))
    Me.dtbln_out_opt_Bmain.Columns.Add("3", Type.GetType("System.String"))
    For i = 0 To .GetUpperBound(0)
        Me.dtbln_out_opt_Bmain.Columns.Add(i + 4, Type.GetType("System.String"))
    Next
    For i = 0 To Me.dtbln_out_opt_Bmain.Columns.Count - 1
        Me.dtbln_out_opt_Bmain.Columns(i).DefaultValue = ""
    Next
    'insert output data
    'headers
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "Description"
    x(1) = "Symbols"
    x(2) = "Units"
    Me.dtbln_out_opt_Bmain.Rows.Add(x)
    'accepted
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "DWEIR SATISFACTORY"
    x(1) = ""
    x(2) = ""
    For i = 0 To .GetUpperBound(0)
        x(i + 3) = IIf(frm_main.try_summary_results(i).accepted, "YES", "NO")
    Next
    Me.dtbln_out_opt_Bmain.Rows.Add(x)
    'Bmain
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "bottom width of main irrigation canal"
    x(1) = "Bmain"
    x(2) = "(m.)"
    For i = 0 To .GetUpperBound(0)
        x(i + 3) = frm_main.try_summary_results(i).B_main
    Next
    Me.dtbln_out_opt_Bmain.Rows.Add(x)
    'total cost
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "Total Cost of Dweir"
    x(1) = "C_tot"
    x(2) = ""
    For i = 0 To .GetUpperBound(0)
        x(i + 3) = frm_main.try_summary_results(i).cost_dweir
    Next
    Me.dtbln_out_opt_Bmain.Rows.Add(x)
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "-------------------------"
    Me.dtbln_out_opt_Bmain.Rows.Add(x)
    'intake cost
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "Cost of Intake"
    x(1) = "C_int"
    x(2) = ""
    For i = 0 To .GetUpperBound(0)
        x(i + 3) = frm_main.try_summary_results(i).cost_int
    Next
    Me.dtbln_out_opt_Bmain.Rows.Add(x)
    'splw cost
    x = Me.dtbln_out_opt_Bmain.NewRow
    x(0) = "Cost of Spillway"
```

```
x(1) = "C_splw"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_splw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'slcw cost
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of Sluiceway"
x(1) = "C_slcw"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_slcw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'guiding wall
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of guiding wall"
x(1) = "C_gw"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_guidingwall
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'sw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of sidewalls"
x(1) = "C_sw"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_sidewalls
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'riprap
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of riprap"
x(1) = "C_riprap"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_riprap
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'flush
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of flushing canal"
x(1) = "C_flush"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_flush
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'div fac
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of diversion facility"
x(1) = "C_div"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_divfac
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'bridge
```

```
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Cost of bridge"
x(1) = "C_bridge"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).cost_bridge
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Bs
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Settling basin width"
x(1) = "Bs"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Bs
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Lsettl
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Settling basin length"
x(1) = "Ks"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Lsettl
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Ks
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway crest Elevation"
x(1) = "Ks"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Ks
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'P
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway height"
x(1) = "Bs"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).P
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'tc
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway Crest width"
x(1) = "tc"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).tc
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Kdes
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Design Discharge Water Surface Elev. over Spillway"
x(1) = "Kdes"
x(2) = "(m.)"
```

```
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).K_des
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Qdes_splw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Design Discharge"
x(1) = "Qdes"
x(2) = "(m3/s.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Qdes
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Qdes_splw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway Design Discharge"
x(1) = "Qdes_splw"
x(2) = "(m3/s.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Qdes_splw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Qdes_slcw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Sluiceway Design Discharge"
x(1) = "Qdes_slcw"
x(2) = "(m3/s.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Qdes_slcw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'common stilling basin
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Common Stilling basin"
x(1) = ""
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).common_sb, "YES", "NO")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Lsb_splw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway Stilling basin length"
x(1) = "Ls_splw"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).sb_splw.L
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Lsb_splw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway sill height"
x(1) = "delta_splw"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).sb_splw.delta
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Lsb_slcw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Sluiceway Stilling basin length"
```

```
x(1) = "Ls_slcw"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).sb_slcw.L
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Lsb_slcw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Sluiceway sill height"
x(1) = "delta_slcw"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).sb_slcw.delta
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'riprap
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "RIPRAP"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Ld
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Riprap length"
x(1) = "Ld"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).riprap_Ld
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'D
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Riprap Stone Diameter"
x(1) = "D"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).riprap_D
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'nrow
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "number of stone rows"
x(1) = "nrow"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).riprap_nrow
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'riprap
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "FLUSHING CANAL"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'D
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Flushing canal Diameter"
x(1) = "Dp"
x(2) = "(m.)"
```

```
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).flush_Dp
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'So
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Flushing canal slope"
x(1) = "So"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).flush_So
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'L
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Flushing canal horizantal length"
x(1) = "Lh"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).flush_Lh
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'SATISFACTORY CRITERIA
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "SEEPAGE"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Lcr
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Creep Length"
x(1) = "Lcr"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).Lcr
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'CH
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "C*H"
x(1) = "C*H"
x(2) = "(m.)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).CH
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'seepage Satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
x(1) = "Lcr >= C*H"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_seepage, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "INTAKE UPLIFT"
```

```
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'intake FSu_int
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Intake FS against Uplift"
x(1) = "FSu_int"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).FSu_int
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSu_int
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
x(1) = "FSu_int >= " & frm_main.int_uplift.inp_Fsu_pro
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_uplift_int, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "SPILLWAY UPLIFT"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSu_splw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Spillway FS against Uplift"
x(1) = "FSu_splw"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).FSu_splw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSu_splw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
x(1) = "FSu_splw >= " & frm_main.splw_uplift.inp_Fsu_pro
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_uplift_splw, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "SLUICEWAY UPLIFT"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSu_slcw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Sluiceway FS against Uplift"
x(1) = "FSu_slcw"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).FSu_slcw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSu_slcw
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
```

```
x(1) = "FSu_slcw >= " & frm_main.slcw_uplift.inp_Fsu_pro
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_uplift_slcw, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "BODY+APRON SLIDING"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSs
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Body+Apron FS against Sliding"
x(1) = "FSs"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).FSs
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSs
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
x(1) = "FSs >= " & frm_main.stab_slide_overt.input_Fs_pro.FSs
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_s, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "BODY+APRON SHEAR&SLIDING"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSss
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Body+Apron FS against Shear&Sliding"
x(1) = "FSss"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).FSss
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSss
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
x(1) = "FSss >= " & frm_main.stab_slide_overt.input_Fs_pro.FSss
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_ss, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "BODY OVERTURNING (full u/s no tw)"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSo
```

```
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Body FS against Overturning"
x(1) = "FSo"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVoheel.FSo
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSo
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory (full u/s no tw)"
x(1) = "FSo >= " & frm_main.stab_slide_overt.input_Fs_pro.FSo
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVoheel.OK_o, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vtoe
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at toe"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVoheel.Vtoe
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vheel
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at heel"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVoheel.Vheel
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmax satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Max. base Pressure "
x(1) = "Vmax <= " & frm_main.stab_slide_overt.input_Fs_pro.Vmax
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVoheel.OK_vmax, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmin satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Min. base Pressure "
x(1) = "Vmin >= " & frm_main.stab_slide_overt.input_Fs_pro.Vmin
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVoheel.OK_vmin, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "BODY OVERTURNING (empty reserv. wrt heel)"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
```

```
'FSo empty reserv
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Body FS against Overturning"
x(1) = "FSo"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVoheel_eu.FSo
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSo
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory (empty res.wrt heel)"
x(1) = "FSo >= " & frm_main.stab_slide_overt.input_Fs_pro.FSo
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVoheel_eu.OK_o, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vtoe
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at toe"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVoheel_eu.Vtoe
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vheel
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at heel"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVoheel_eu.Vheel
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmax satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Max. base Pressure "
x(1) = "Vmax <= " & frm_main.stab_slide_overt.input_Fs_pro.Vmax
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVoheel_eu.OK_vmax, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmin satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Min. base Pressure "
x(1) = "Vmin >= " & frm_main.stab_slide_overt.input_Fs_pro.Vmin
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVoheel_eu.OK_vmin, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "BODY OVERTURNING (empty reserv. wrt toe)"
```

```
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSo empty reserv wrt toe
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Body FS against Overturning"
x(1) = "FSo"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVotoe_eu.FSo
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSo
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory (empty res.wrt toe)"
x(1) = "FSo >= " & frm_main.stab_slide_overt.input_Fs_pro.FSo
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVotoe_eu.OK_o, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vtoe
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at toe"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVotoe_eu.Vtoe
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vheel
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at heel"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVotoe_eu.Vheel
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmax satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Max. base Pressure "
x(1) = "Vmax <= " & frm_main.stab_slide_overt.input_Fs_pro.Vmax
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVotoe_eu.OK_vmax, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmin satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Min. base Pressure "
x(1) = "Vmin >= " & frm_main.stab_slide_overt.input_Fs_pro.Vmin
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVotoe_eu.OK_vmin, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
```

```
x(0) = "SIDEWALLS (Spillway Side)"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'FSs
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Sidewalls FS against Sliding"
x(1) = "FSs"
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).FSs_sw_splw
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'satisfactory_FSs
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory"
x(1) = "FSs >= " & frm_main.stab_slide_overt.input_Fs_pro.FSs_sw
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).OK_s_sw_splw, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vtoe
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at toe"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVo_sw_splw.Vtoe
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vheel
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Base pressure at heel"
x(1) = "Vtoe"
x(2) = "(kN/m2)"
For i = 0 To .GetUpperBound(0)
    x(i + 3) = frm_main.try_summary_results(i).MVo_sw_splw.Vheel
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmax satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Max. base Pressure "
x(1) = "Vmax <= " & frm_main.stab_slide_overt.input_Fs_pro.Vmax_sw
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVo_sw_splw.OK_vmax, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
'Vmin satisfactory
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "Satisfactory Min. base Pressure "
x(1) = "Vmin >= " & frm_main.stab_slide_overt.input_Fs_pro.Vmin_sw
x(2) = ""
For i = 0 To .GetUpperBound(0)
    x(i + 3) = IIf(frm_main.try_summary_results(i).MVo_sw_splw.OK_vmin, "OK", "not OK")
Next
Me.dtbln_out_opt_Bmain.Rows.Add(x)
x = Me.dtbln_out_opt_Bmain.NewRow
x(0) = "-------------------------"
Me.dtbln_out_opt_Bmain.Rows.Add(x)
```

```
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "SIDEWALLS (Sluiceway Side)"
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        'FSo empty reserv wrt toe
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "Sidewalls FS against Sliding"
        x(1) = "FSs"
        x(2) = ""
        For i = 0 To .GetUpperBound(0)
            x(i + 3) = frm_main.try_summary_results(i).FSs_sw_slcw
        Next
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        'satisfactory_FSo
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "Satisfactory"
        x(1) = "FSs >= " & frm_main.stab_slide_overt.input_Fs_pro.FSs_sw
        x(2) = ""
        For i = 0 To .GetUpperBound(0)
            x(i + 3) = IIf(frm_main.try_summary_results(i).OK_s_sw_slcw, "OK", "not OK")
        Next
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        x = Me.dtbln_out_opt_Bmain.NewRow
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        'Vtoe
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "Base pressure at toe"
        x(1) = "Vtoe"
        x(2) = "(kN/m2)"
        For i = 0 To .GetUpperBound(0)
            x(i + 3) = frm_main.try_summary_results(i).MVo_sw_slcw.Vtoe
        Next
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        'Vheel
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "Base pressure at heel"
        x(1) = "Vtoe"
        x(2) = "(kN/m2)"
        For i = 0 To .GetUpperBound(0)
            x(i + 3) = frm_main.try_summary_results(i).MVo_sw_slcw.Vheel
        Next
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        'Vmax satisfactory
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "Satisfactory Max. base Pressure "
        x(1) = "Vmax <= " & frm_main.stab_slide_overt.input_Fs_pro.Vmax_sw
        x(2) = ""
        For i = 0 To .GetUpperBound(0)
            x(i + 3) = IIf(frm_main.try_summary_results(i).MVo_sw_slcw.OK_vmax, "OK", "not OK")
        Next
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
        'Vmin satisfactory
        x = Me.dtbln_out_opt_Bmain.NewRow
        x(0) = "Satisfactory Min. base Pressure "
        x(1) = "Vmin >= " & frm_main.stab_slide_overt.input_Fs_pro.Vmin_sw
        x(2) = ""
        For i = 0 To .GetUpperBound(0)
            x(i + 3) = IIf(frm_main.try_summary_results(i).MVo_sw_slcw.OK_vmin, "OK", "not OK")
        Next
        Me.dtbln_out_opt_Bmain.Rows.Add(x)
    End With
End Sub
```

```
#End Region
#Region "Printout procedures"
    Private Sub print_preview(ByVal dtable As DataTable)
        Me.DataGridEx2.PageSettings = CustomControls.PageSetup.PageSettings
        Me.DataGridEx2.PrintPreview(Nothing, dtable,
CType(Me.BindingContext(Me.DataGridEx2.DataSource), CurrencyManager), 25, "Do you wish to
continue?", " ")
    End Sub
    Private Sub print_out(ByVal dtable As DataTable)
        Me.DataGridEx2.PageSettings = CustomControls.PageSetup.PageSettings
        Me.DataGridEx2.Print(Nothing, dtable, CType(Me.BindingContext(Me.DataGridEx2.DataSource),
CurrencyManager), " ")
    End Sub
#End Region
#End Region
    Private Sub MenuItem1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem1.Click
        Me.DataGridEx2.CaptionText = "Intake Water Surface Profile Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_int)
        Me.DataGridEx2.DataSource = Me.dtbln_out_int
    End Sub
    Private Sub MenuItem2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem2.Click
        Me.DataGridEx2.CaptionText = "Intake Computations Summary Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_int2)
        Me.DataGridEx2.DataSource = Me.dtbln_out_int2
    End Sub
    Private Sub MenuItem4_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles
MenuItem4.Click
        frm_outputs.chart_no = 0
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub GroupBox1_Enter(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
GroupBox1.Enter
    End Sub
    Private Sub MenuItem12_Click(ByVal sender As System.Object, ByVal e As System.EventArgs)
    End Sub
    Private Sub MenuItem10_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem10.Click
        Me.DataGridEx2.CaptionText = "Spillway - Sluiceway Discharges Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_splw_slcw)
        Me.DataGridEx2.DataSource = Me.dtbln_out_splw_slcw
    End Sub
    Private Sub MenuItem11_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem11.Click
        Me.DataGridEx2.CaptionText = "Energy Dissipators Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_energydis)
        Me.DataGridEx2.DataSource = Me.dtbln_out_energydis
    End Sub
    Private Sub MenuItem3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem3.Click
        Me.print_preview(Me.DataGridEx2.DataSource)
    End Sub
    Private Sub MenuItem5_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem5.Click
        Me.print_out(Me.DataGridEx2.DataSource)
        Me.DataGridEx2.PageSettings = CustomControls.PageSetup.PageSettings
    End Sub
    Private Sub MenuItem6_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem6.Click
```

```
        Me.DataGridEx2.CaptionText = "Seepage Computations Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_seepage)
        Me.DataGridEx2.DataSource = Me.dtbln_out_seepage
    End Sub
    Private Sub MenuItem7_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem7.Click
    End Sub
    Private Sub MenuItem16_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem16.Click
        Me.DataGridEx2.PageSetup()
        Me.DataGridEx2.PageSettings = CustomControls.PageSetup.PageSettings
    End Sub
    Private Sub MenuItem17_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem17.Click
        frm_outputs.chart_no = 1
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub MenuItem18_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem18.Click
        frm_outputs.chart_no = 2
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub MenuItem19_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem19.Click
        Me.DataGridEx2.CaptionText = "Intake Stability against Uplift Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_upl_int)
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_upl_int
    End Sub
    Private Sub MenuItem20_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem20.Click
        Me.DataGridEx2.CaptionText = "Spillway Stability against Uplift Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_upl_splw)
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_upl_splw
    End Sub
    Private Sub MenuItem21_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem21.Click
        Me.DataGridEx2.CaptionText = "Sluiceway Stability against Uplift Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_upl_slcw)
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_upl_slcw
    End Sub
    Private Sub MenuItem9_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem9.Click
        Me.DataGridEx2.CaptionText = "Spillway Body Stability against Overturning Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_overt_splw)
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_overt_splw
    End Sub
    Private Sub MenuItem23_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem23.Click
        DataSetExport.Export(Me.DataGridEx2.DataSource)
    End Sub
    Private Sub MenuItem24_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem24.Click
        DataSetExport.SendEMail(Me.DataGridEx2.DataSource)
    End Sub
    Private Sub MenuItem13_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem13.Click
        Me.DataGridEx2.CaptionText = "Spillway Body+Apron Stability against Sliding Results Table (Full u/s
no Tailwater):"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_slide_splw)
```

```
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_slide_splw
    End Sub
    Private Sub MenuItem25_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem25.Click
        Me.DataGridEx2.CaptionText = "Spillway Body Stability against Overturning Results Table (Empty
reservoir wrt Toe):"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_overt_splw_er_wrt_toe)
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_overt_splw_er_wrt_toe
    End Sub
    Private Sub MenuItem26_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem26.Click
        Me.DataGridEx2.CaptionText = "Spillway Body Stability against Overturning Results Table (Empty
reservoir wrt Heel):"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_stab_overt_splw_er_wrt_heel)
        Me.DataGridEx2.DataSource = Me.dtbln_out_stab_overt_splw_er_wrt_heel
    End Sub
    Private Sub MenuItem27_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem27.Click
        Me.DataGridEx2.CaptionText = "Crest Elevation of u/s Levees Results Table"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_levees)
        Me.DataGridEx2.DataSource = Me.dtbln_out_levees
    End Sub
    Private Sub MenuItem28_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem28.Click
        frm_outputs.chart_no = 3
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub MenuItem29_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem29.Click
        Me.DataGridEx2.CaptionText = "Riprap Design Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_riprap)
        Me.DataGridEx2.DataSource = Me.dtbln_out_riprap
    End Sub
    Private Sub MenuItem30_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem30.Click
        Me.DataGridEx2.CaptionText = "Flushing Canal Design Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_flush)
        Me.DataGridEx2.DataSource = Me.dtbln_out_flush
    End Sub
    Private Sub MenuItem31_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem31.Click
        Me.DataGridEx2.CaptionText = "WSP for optimum width Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_div_wsp)
        Me.DataGridEx2.DataSource = Me.dtbln_out_div_wsp
    End Sub
    Private Sub MenuItem32_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem32.Click
        Me.DataGridEx2.CaptionText = "Cost analysis for different canal widths Summary Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_div_summary)
        Me.DataGridEx2.DataSource = Me.dtbln_out_div_summary
    End Sub
    Private Sub MenuItem33_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem33.Click
        frm_outputs.chart_no = 4
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub MenuItem34_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem34.Click
        frm_outputs.chart_no = 5
```

```
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub MenuItem42_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem42.Click
        frm_outputs.chart_no = 6
        Dim frm_graph As New frm_charts()
        frm_graph.Show()
    End Sub
    Private Sub MenuItem41_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem41.Click
        Me.DataGridEx2.CaptionText = "Summary of the Optimization Tries Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_opt_Bmain)
        Me.DataGridEx2.DataSource = Me.dtbln_out_opt_Bmain
    End Sub
    Private Sub MenuItem43_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem43.Click
        Me.DataGridEx2.CaptionText = "Costs of the Structures Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_costs)
        Me.DataGridEx2.DataSource = Me.dtbln_out_costs
    End Sub
    Private Sub MenuItem35_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem35.Click
        Me.DataGridEx2.CaptionText = "Sidewalls Stability against Sliding Results Table:"
        Me.DataGridEx2.AdjustColumnWidths(Me.dtbln_out_sw_splw_slide)
        Me.DataGridEx2.DataSource = Me.dtbln_out_sw_splw_slide
    End Sub
End Class
'*-------------------------------------------------------------------------------------------------------------------*
'|                                   END OF FORM-4                                                                   |
'*-------------------------------------------------------------------------------------------------------------------*


'*-------------------------------------------------------------------------------------------------------------------*
'|                                   FORM-11    : Form11.vb                                                          |
'*-------------------------------------------------------------------------------------------------------------------*
Imports scpl2
Imports dweir_code.General_Hydraulic_Functions
Imports System.Math
Public Class frm_charts
    Inherits System.Windows.Forms.Form
#Region " Windows Form Designer generated code "
    Public Sub New()
        MyBase.New()
        'This call is required by the Windows Form Designer.
        InitializeComponent()
        'Add any initialization after the InitializeComponent() call
    End Sub
    'Form overrides dispose to clean up the component list.
    Protected Overloads Overrides Sub Dispose(ByVal disposing As Boolean)
        If disposing Then
            If Not (components Is Nothing) Then
                components.Dispose()
            End If
        End If
        MyBase.Dispose(disposing)
    End Sub
    'Required by the Windows Form Designer
    Private components As System.ComponentModel.IContainer
    'NOTE: The following procedure is required by the Windows Form Designer
    'It can be modified using the Windows Form Designer.
```

```
    'Do not modify it using the code editor.
    'This part of code is generated automatically. Details are hidden.
#End Region
    Const serie_size As Integer = 20 'max serie sixe to show in a graph together
    'graphical elements (series= 2 of them forms a serie; because they are related eachother; line rep and point
rep)
    Private series As New Collection()
    Private xsec_int(11) As xsec_hyd
    Private Sub frm_charts_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        Me.load_chart_data(frm_outputs.chart_no)
    End Sub
#Region "general chart procedures"
    Private Sub add_plot(ByVal x() As Single, ByVal y() As Single, ByVal lcolor As Color, ByVal serie_name
As String)
        Dim lp As New LinePlot(New ArrayAdapter(x, y)) 'to plot line
        Dim pp As New PointPlot(New ArrayAdapter(x, y))     'to plot point
        With Me.chart
            lp.Pen = New Pen(lcolor, 2)
            pp.Marker.Type = MarkerType.Cross1
            pp.Marker.Pen = New Pen(lcolor, 5)
            lp.Label = serie_name
            pp.Label = serie_name & " points"
        End With
        series.Add(lp, serie_name & "_l")
        series.Add(pp, serie_name & "_p")
    End Sub
    Private Sub remove_plot(ByVal serie_name As String)
        Me.chart.remove(series.Item(serie_name & "_l"))
        Me.chart.remove(series.Item(serie_name & "_p"))
        series.Remove(serie_name & "_l")
        series.Remove(serie_name & "_p")
    End Sub
    Private Sub load_default_chart_pro()
        'default chart properties
        With Me.chart
            .MajorGridPen.DashStyle = Drawing.Drawing2D.DashStyle.Dash
            .MajorGridPen.Color = Color.Gray
            .MinorGridPen.Color = Color.LightGray
            .MinorGridPen.DashStyle = Drawing.Drawing2D.DashStyle.Dot
            .TitleFont = New Font("Arail", 9, FontStyle.Bold, GraphicsUnit.Point)
            .XAxis1.LabelFont = New Font("Arial", 8, FontStyle.Italic, GraphicsUnit.Point)
            .YAxis1.LabelFont = New Font("Arial", 8, FontStyle.Italic, GraphicsUnit.Point)
            .XAxis1.GridDetail = Axis.GridType.None
            .YAxis1.GridDetail = Axis.GridType.None
            .LegendAttachTo(XAxisPosition.Bottom, YAxisPosition.Right)
            .HorizontalEdgeLegendPlacement = Legend.Placement.Inside
            .VerticalEdgeLegendPlacement = Legend.Placement.Inside
            .LegendBorderStyle = Legend.BorderType.Line
            .ShowLegend = True
            .Refresh()
            'refresh the graph options to all checked
            Me.MenuItem2.Checked = True
            Me.MenuItem5.Checked = False
            Me.MenuItem6.Checked = False
        End With
    End Sub
    Private Sub show_charts(ByVal title As String, ByVal xaxis As String, ByVal yaxis As String)
        Dim i As Integer
        'reset chart firstly
        'by this algorithm, everytime, chart is rescaled according to the existing plot data
```

```
        Me.chart.Clear()
        For i = 1 To series.Count 'for collections indexs starts from 1
            Me.chart.Add(series.Item(i))
        Next
        'refresh default view everytime...
        load_default_chart_pro()
        ' every time to show chart titles
        Me.chart.Title = title
        Me.chart.XAxis1.Label = xaxis
        Me.chart.YAxis1.Label = yaxis
        Me.chart.Refresh()
    End Sub
    Private Sub load_chart_data(ByVal chart_no As Byte)
        Select Case chart_no
            Case 0 'intake water surface profile
                load_intake_wsp()
            Case 1 'K versus discharge graph (spillw sluiceway)Rating curve
                load_K_versus_Q()
            Case 2 'seepage
                load_seepage_path()
            Case 3 'crest el. of levees
                load_levees_wsp()
            Case 4
                load_div_wsp()
            Case 5
                load_div_costs()
            Case 6
                load_opt_Bmain_costs()
        End Select
    End Sub
#End Region
#Region "intake wsp"
    Private Sub add_int_plot_Kb()
        Dim i As Integer
        Dim xx(11), yy(11) As Single
        For i = 0 To xsec_int.GetUpperBound(0)
            xx(i) = xsec_int(i).km_xsec_p
            yy(i) = xsec_int(i).Kb_pro
        Next
        Me.add_plot(xx, yy, Color.Brown, "Ground surface")
    End Sub
    Private Sub add_int_plot_HGL()
        Dim i As Integer
        Dim xx(11), yy(11) As Single
        For i = 0 To xsec_int.GetUpperBound(0)
            xx(i) = xsec_int(i).km_xsec_p
            yy(i) = xsec_int(i).Hgl_pro
        Next
        Me.add_plot(xx, yy, Color.Blue, "HGL")
    End Sub
    Private Sub add_int_plot_EGL()
        Dim i As Integer
        Dim xx(11), yy(11) As Single
        For i = 0 To xsec_int.GetUpperBound(0)
            xx(i) = xsec_int(i).km_xsec_p
            yy(i) = xsec_int(i).Egl_pro
        Next
        Me.add_plot(xx, yy, Color.Green, "EGL")
    End Sub
    Private Sub load_intake_wsp()
        If Not (IsNothing(frm_main.intake_des)) Then  'if intake computations were made or not
```

```
            Me.ToolBarButton2.DropDownMenu = Me.mnu_graph_int
            'readjust xsec for plot
            With frm_main.intake_des
                xsec_int(0) = .xsec_pro(0)
                xsec_int(1) = .xsec_pro(1)
                xsec_int(2) = New xsec_hyd(.xsec_pro(1))
                xsec_int(2).km_xsec_p = .xsec_pro(2).km_xsec_p
                xsec_int(3) = .xsec_pro(2)
                xsec_int(4) = .xsec_pro(3)
                xsec_int(5) = .xsec_pro(4)
                xsec_int(6) = .xsec_pro(5)
                xsec_int(7) = .xsec_pro(6)
                xsec_int(8) = New xsec_hyd(.xsec_pro(6))
                xsec_int(8).km_xsec_p = .xsec_pro(7).km_xsec_p
                xsec_int(9) = .xsec_pro(7)
                xsec_int(10) = .xsec_pro(8)
                xsec_int(11) = New xsec_hyd(.xsec_pro(8))
                xsec_int(11).km_xsec_p -= 1
            End With
            Me.add_int_plot_Kb()
            Me.add_int_plot_HGL()
            Me.add_int_plot_EGL()
            Me.show_charts("Intake Water Surface Elevations", "Horizantal distance (m.)", "Elevations (m.)")
        End If
    End Sub
#End Region
#Region "spilway sluiceway rating curve"
    Private Sub load_K_versus_Q()
        If Not (IsNothing(frm_main.splw_Q)) Then  'if splw_Q computations were made or not
            Me.ToolBarButton2.DropDownMenu = Me.mnu_graph_splw_Q
            Me.add_plot_K_Qtot()
            Me.add_plot_K_Qsplw()
            Me.add_plot_K_Qslcw()
            Me.show_charts("Rating Curve", "Discharges: Q (m3/s.)", "Water surface elevations: K (m.)")
            Me.chart.XAxis1.WorldMin = 0
        End If
    End Sub
    Private Sub add_plot_K_Qtot()
        With frm_main.splw_Q
            Me.add_plot(.input_data_pro.Q, .K_pro, Color.Green, "Total Discharge")
        End With
    End Sub
    Private Sub add_plot_K_Qsplw()
        With frm_main.splw_Q
            Me.add_plot(.Qs_pro, .K_pro, Color.DarkBlue, "Spillway Discharge")
        End With
    End Sub
    Private Sub add_plot_K_Qslcw()
        With frm_main.splw_Q
            Me.add_plot(.Qsl_pro, .K_pro, Color.Blue, "Sluiceway Discharge")
        End With
    End Sub
#End Region
#Region "seepage path"
    Private Sub load_seepage_path()
        If Not (IsNothing(frm_main.seepage_des)) Then  'if splw_Q computations were made or not
            Me.ToolBarButton2.DropDownMenu = Me.mnu_graph_seepage
            Me.add_plot_seepage_path()
            Me.show_charts("Seepage Path (Lane's Creep Analysis)", "Horizantal distances: (m.)", "Elevations:
(m.)")
        End If
```

```
    End Sub
    Private Sub add_plot_seepage_path()
        Dim i As Integer
        Dim epsilon As Single = 0.5
        With frm_main.seepage_des
            Dim xx(.inp_creep_path_pro.GetUpperBound(0)) As Single
            Dim yy(.inp_creep_path_pro.GetUpperBound(0)) As Single
            For i = 0 To xx.GetUpperBound(0)
                xx(i) = .inp_creep_path_pro(i).x
                yy(i) = .inp_creep_path_pro(i).y
            Next
            'adjust u/s blanket thickness for visuality
            xx(2) += epsilon
            xx(3) += epsilon
            Me.add_plot(xx, yy, Color.Blue, "Seepage path")
        End With
    End Sub
#End Region
#Region "optimization Bmain costs"
    Private Sub load_opt_Bmain_costs()
        If (Not IsNothing(frm_main.try_summary_results) And Not
IsNothing(frm_main.try_summary_results_OK)) Then   'if intake computations were made or not
            Me.ToolBarButton2.DropDownMenu = Nothing
            Me.add_plot_dweir_costs_all()
            Me.add_plot_dweir_costs_accepted()
            Me.show_charts("Cost Analysis", "Bottom width: B(m.)", "Cost: CT ($)")
        End If
    End Sub
    Private Sub add_plot_dweir_costs_all()
        Dim i As Integer
        Dim xx(frm_main.try_summary_results.GetUpperBound(0)) As Single
        Dim yy(frm_main.try_summary_results.GetUpperBound(0)) As Single
        For i = 0 To frm_main.try_summary_results.GetUpperBound(0)
            xx(i) = frm_main.try_summary_results(i).B_main
            yy(i) = frm_main.try_summary_results(i).cost_dweir
        Next
        Me.add_plot(xx, yy, Color.Red, "costs_all")
    End Sub
    Private Sub add_plot_dweir_costs_accepted()
        Dim i As Integer
        Dim xx(frm_main.try_summary_results_OK.GetUpperBound(0)) As Single
        Dim yy(frm_main.try_summary_results_OK.GetUpperBound(0)) As Single
        For i = 0 To frm_main.try_summary_results_OK.GetUpperBound(0)
            xx(i) = frm_main.try_summary_results_OK(i).B_main
            yy(i) = frm_main.try_summary_results_OK(i).cost_dweir
        Next
        Me.add_plot(xx, yy, Color.Blue, "costs_accepted")
    End Sub
#End Region  'to be added
    Private Sub chart_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
chart.Load
    End Sub
    Private Sub MenuItem3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem3.Click
        Me.PrintPreviewDialog1.ShowDialog()
    End Sub
    Private Sub MenuItem1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem1.Click
        Me.PageSetupDialog1.ShowDialog()
    End Sub
```

```
    Private Sub MenuItem4_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem4.Click
        If PrintDialog1.ShowDialog() = DialogResult.OK Then
            Try
                PrintDocument1.Print()
            Catch
                MsgBox("An error occured during printing", MsgBoxStyle.Exclamation, "WIN-DWEIR / Printout")
            End Try
        End If
    End Sub
    Private Sub PrintDocument1_PrintPage(ByVal sender As System.Object, ByVal e As
System.Drawing.Printing.PrintPageEventArgs) Handles PrintDocument1.PrintPage
        Me.chart.Draw(e.Graphics, e.MarginBounds)
        e.HasMorePages = False
    End Sub
    Private Sub MenuItem7_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem7.Click
        If Not Me.MenuItem7.Checked Then
            Me.add_int_plot_Kb()
            Me.MenuItem7.Checked = Not Me.MenuItem7.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("Ground surface")
                Me.MenuItem7.Checked = Not Me.MenuItem7.Checked
            End If
        End If
        Me.show_charts("Intake Water Surface Elevations", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem8_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem8.Click
        If Not Me.MenuItem8.Checked Then
            Me.add_int_plot_HGL()
            Me.MenuItem8.Checked = Not Me.MenuItem8.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("HGL")
                Me.MenuItem8.Checked = Not Me.MenuItem8.Checked
            End If
        End If
        Me.show_charts("Intake Water Surface Elevations", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem9_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem9.Click
        If Not Me.MenuItem9.Checked Then
            Me.add_int_plot_EGL()
            Me.MenuItem9.Checked = Not Me.MenuItem9.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("EGL")
                Me.MenuItem9.Checked = Not Me.MenuItem9.Checked
            End If
        End If
        Me.show_charts("Intake Water Surface Elevations", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem10_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem10.Click
        If Not Me.MenuItem10.Checked Then
            Me.add_plot_K_Qtot()
            Me.MenuItem10.Checked = Not Me.MenuItem10.Checked
        Else
            If series.Count > 2 Then
```

```
            Me.remove_plot("Total Discharge")
            Me.MenuItem10.Checked = Not Me.MenuItem10.Checked
          End If
        End If
        Me.show_charts("Rating Curve", "Discharges: Q (m3/s.)", "Water surface elevations: K (m.)")
    End Sub
    Private Sub MenuItem11_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem11.Click
        If Not Me.MenuItem11.Checked Then
          Me.add_plot_K_Qsplw()
          Me.MenuItem11.Checked = Not Me.MenuItem11.Checked
        Else
          If series.Count > 2 Then
            Me.remove_plot("Spillway Discharge")
            Me.MenuItem11.Checked = Not Me.MenuItem11.Checked
          End If
        End If
        Me.show_charts("Rating Curve", "Discharges: Q (m3/s.)", "Water surface elevations: K (m.)")
    End Sub
    Private Sub MenuItem12_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem12.Click
        If Not Me.MenuItem12.Checked Then
          Me.add_plot_K_Qslcw()
          Me.MenuItem12.Checked = Not Me.MenuItem12.Checked
        Else
          If series.Count > 2 Then
            Me.remove_plot("Sluiceway Discharge")
            Me.MenuItem12.Checked = Not Me.MenuItem12.Checked
          End If
        End If
        Me.show_charts("Rating Curve", "Discharges: Q (m3/s.)", "Water surface elevations: K (m.)")
    End Sub
    Private Sub MenuItem14_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem14.Click
        If Not Me.MenuItem14.Checked Then
          Me.add_plot_seepage_path()
          Me.MenuItem14.Checked = Not Me.MenuItem14.Checked
        Else
          If series.Count > 2 Then
            Me.remove_plot("Seepage path")
            Me.MenuItem14.Checked = Not Me.MenuItem14.Checked
          End If
        End If
        Me.show_charts("Seepage Path (Lane's Creep Analysis)", "Horizantal distances: (m.)", "Elevations:
(m.)")
    End Sub
    Private Sub MenuItem13_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem13.Click
        If Not Me.MenuItem13.Checked Then
          Me.add_plot_levees_Kb()
          Me.MenuItem13.Checked = Not Me.MenuItem13.Checked
        Else
          If series.Count > 2 Then
            Me.remove_plot("Bottom EL")
            Me.MenuItem13.Checked = Not Me.MenuItem13.Checked
          End If
        End If
        Me.show_charts("Crest Elevation of u/s Levees", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem15_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem15.Click
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        If Not Me.MenuItem15.Checked Then
            Me.add_plot_levees_HGL()
            Me.MenuItem15.Checked = Not Me.MenuItem15.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("HGL")
                Me.MenuItem15.Checked = Not Me.MenuItem15.Checked
            End If
        End If
        Me.show_charts("Crest Elevation of u/s Levees", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem16_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem16.Click
        If Not Me.MenuItem16.Checked Then
            Me.add_plot_levees_EGL()
            Me.MenuItem16.Checked = Not Me.MenuItem16.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("EGL")
                Me.MenuItem16.Checked = Not Me.MenuItem16.Checked
            End If
        End If
        Me.show_charts("Crest Elevation of u/s Levees", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem17_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem17.Click
        If Not Me.MenuItem17.Checked Then
            Me.add_plot_levees_El_crest()
            Me.MenuItem17.Checked = Not Me.MenuItem17.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("Crest EL")
                Me.MenuItem17.Checked = Not Me.MenuItem17.Checked
            End If
        End If
        Me.show_charts("Crest Elevation of u/s Levees", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem18_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem18.Click
        If Not Me.MenuItem18.Checked Then
            Me.add_plot_div_wsp_Kb()
            Me.MenuItem18.Checked = Not Me.MenuItem18.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("Bottom EL")
                Me.MenuItem18.Checked = Not Me.MenuItem18.Checked
            End If
        End If
        Me.show_charts("WSP of diversion canal", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem19_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem19.Click
        If Not Me.MenuItem19.Checked Then
            Me.add_plot_div_wsp_HGL()
            Me.MenuItem19.Checked = Not Me.MenuItem19.Checked
        Else
            If series.Count > 2 Then
                Me.remove_plot("HGL")
                Me.MenuItem19.Checked = Not Me.MenuItem19.Checked
            End If
        End If
```

```
        Me.show_charts("WSP of diversion canal", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem20_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem20.Click
        If Not Me.MenuItem20.Checked Then
            Me.add_plot_div_wsp_EGL()
            Me.MenuItem20.Checked = Not Me.MenuItem20.Checked
        Else
            If series.Count > 2 Then '1 for line 1 for points
                Me.remove_plot("EGL")
                Me.MenuItem20.Checked = Not Me.MenuItem20.Checked
            End If
        End If
        Me.show_charts("WSP of diversion canal", "Horizantal distance (m.)", "Elevations (m.)")
    End Sub
    Private Sub MenuItem5_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem5.Click
        Me.MenuItem5.Checked = Not Me.MenuItem5.Checked
        If Me.MenuItem5.Checked Then
            Me.chart.XAxis1.GridDetail = Axis.GridType.Coarse
            Me.chart.YAxis1.GridDetail = Axis.GridType.Coarse
        Else
            Me.MenuItem6.Checked = False
            Me.chart.XAxis1.GridDetail = Axis.GridType.None
            Me.chart.YAxis1.GridDetail = Axis.GridType.None
        End If
        Me.chart.Refresh()
    End Sub
    Private Sub MenuItem2_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem2.Click
        Me.MenuItem2.Checked = Not Me.MenuItem2.Checked
        Me.chart.ShowLegend = Me.MenuItem2.Checked
        Me.chart.Refresh()
    End Sub
    Private Sub MenuItem6_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MenuItem6.Click
        Me.MenuItem6.Checked = Not Me.MenuItem6.Checked
        If Me.MenuItem6.Checked Then
            Me.MenuItem5.Checked = True
            Me.chart.XAxis1.GridDetail = Axis.GridType.Fine
            Me.chart.YAxis1.GridDetail = Axis.GridType.Fine
        Else
            Me.chart.XAxis1.GridDetail = Axis.GridType.Coarse
            Me.chart.YAxis1.GridDetail = Axis.GridType.Coarse
        End If
        Me.chart.Refresh()
    End Sub
End Class
'*-----------------------------------------------------------------------------------------------------*
'|                              END OF FORM-11                                                          |
'*-----------------------------------------------------------------------------------------------------*

'*-----------------------------------------------------------------------------------------------------*
'|                              NOTE:                                                                   |
'| The program uses two pre-compiled modules whose names are “scpl2.dll” and “CustomControls.dll”. Since|
'| they are pre-compiled modules, their source codes are not available, so the source codes of these modules |
'| can not be presented here. Program developer should be accessed for the integration of these modules into |
'| the program.                                                                                         |
'*-----------------------------------------------------------------------------------------------------*
```