Assessment of the caesium-137 flux adsorbed to suspended sediment in a reservoir in the contaminated Fukushima region in Japan

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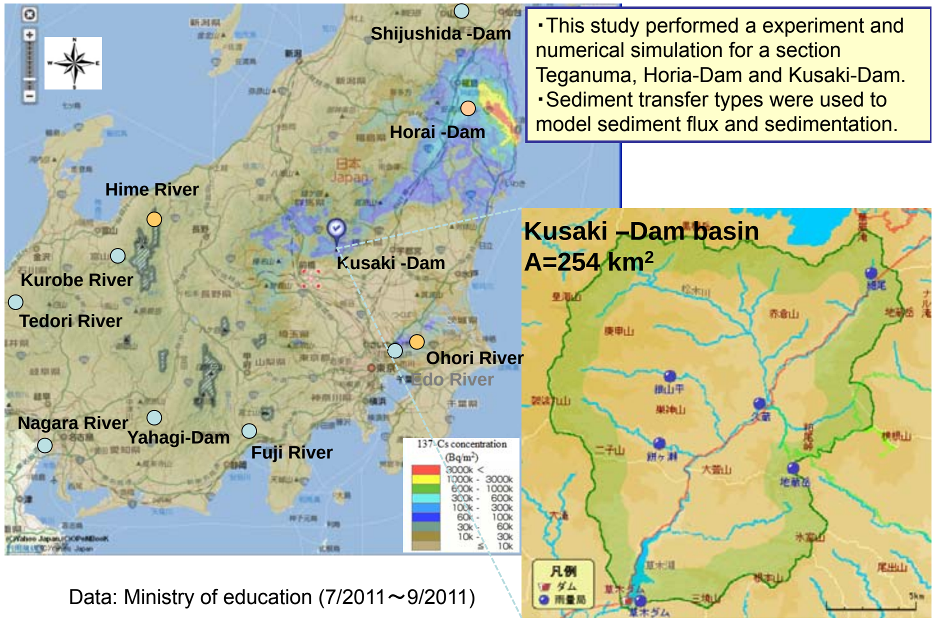
6/6/2013, CREST meeting, #7

河川流域における放射性物質動態モデル開発状況

- 琵琶湖研究所
  - 大気と陸域モデルを開発中(琵琶湖プロジェクトの時のモデルがベースとなっている)
  - 大気モデルの詳細は未だ公表できない
  - 陸域モデルは、斜面・河道サブモデル(OHyMoS, kinematic model)ベース
  - 解像度は500m
  - 浮遊砂の粒径別にパラメータ化
  - 土砂水理学的な手法は考慮されていない
  - 貯水池は、WEC生態系モデル(ダム水源地センター)ベース
  - →河川構造物やダムにおける背上げ背水による堆積物の影響を考慮しづらい
- 近藤グループ
  - USLEモデルベースにパラメータを設定
  - 解像度は10km程度
  - →経験則に基づき、里山の保全に資することを目的としている
- 恩田グループ
  - 阿武隈川における詳細な調査に基づき、開発中
  - kinematic waveモデルベースに放射性セシウムを対象に、物理崩壊、河道における移動、植物による吸収などをパラメータ化し、SSと河川の溶存性セシウムの濃度の関係を示している。山腹斜面における降雨流出量はkinematic wave モデルにもとづいて算定　　(村上先生、放射能勉強会資料より)

● Location map showing the 137-Cs concentration and our study sites

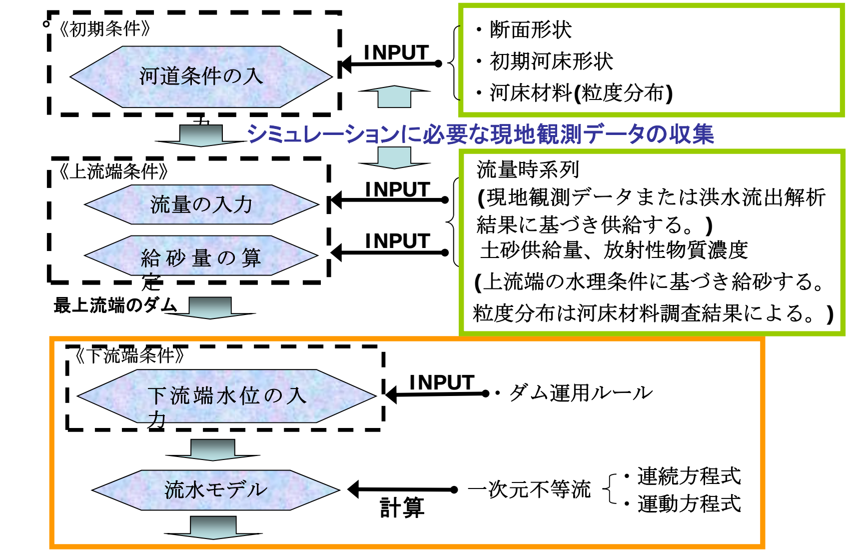


・This study performed a experiment and numerical simulation for a section Teganuma, Horia-Dam and Kusaki-Dam.
・Sediment transfer types were used to model sediment flux and sedimentation.

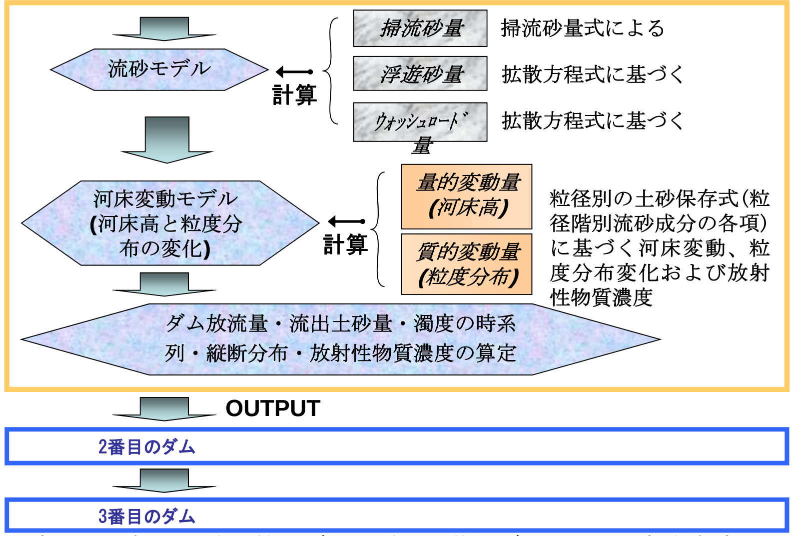
Data: Ministry of education (7/2011～9/2011)

●土砂水理学に基づく放射性動態シミュレーションの構成1

本検討で構築した放射性物資動態シミュレーションモデルの構成は、以下のとおりである



●土砂水理学に基づく放射性動態シミュレーションの構成2



小滝川を対象に土砂動態モデルの検証、草木ダムにおいて放射性物質動態の力学過程の導入を行った。

●Governing equation for water flow

The governing equations of hydrodynamic model can be written in simplified form as

$$\frac{\partial Q}{\partial x} = q \qquad (1)$$

$$\frac{1}{gA}\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + \frac{\partial H}{\partial x} + I_e = 0 \qquad (2)$$

Eq. (1) is a continuity equation with no lateral inflow or outflow, where Q is the water discharge in the x-direction. Eq. (2) is a dynamic equation of gradually varying flow without local losses, where Q is the flow volume, A is the cross-sectional area of the stream, g is the acceleration from gravity, I_e is the energy-loss gradient, and H is the water level evaluated by the equation below, using Manning's coefficient of roughness when considering the energy loss.

●Governing equation for sediment transfer

The governing equations of sediment transfer can be written in simplified form.

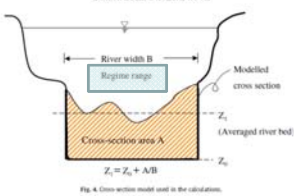
The degree of riverbed change, sediment volume, and grain size distribution as a result of the interaction of debris flow, bedload, suspended load, and wash load fractions is depicted by the following formula:

$$\frac{\partial Z}{\partial t} + \frac{1}{B}\left[\sum_{k=1}^{Nb}\left(\frac{B_s}{1-\lambda_{deb}}\frac{\partial q_{debxk}}{\partial x} + \frac{B_s}{1-\lambda_b}\frac{\partial q_{bxk}}{\partial x} + \frac{B_s(E_{sk}-D_{sk})}{1-\lambda_s}\right) + \sum_{k=Nb+1}^{Nd}\frac{B_s(E_{wk}-D_{wk})}{1-\lambda_w}\right] = 0$$

river bed variation per unit time | river bed variation for bedload | river bed variation for suspended load | river bed variation for wash load

Turbidity substance

where Bs is the width of the flow of the particle, q_{bxk} is the quantity of sediment, E_{sk} and E_{wk} are the pickup flux, D_{sk} and D_{wk} are the depositional flux, and λ_{deb}, λ_b, λs, and λ_w are the gap rate of the particles.



●Governing equation for ceasium-137 transfer

The river channel cesium-137 concentration incorporating the effects of porosity as

$$\frac{\partial C_{c-137}}{\partial t} = \kappa \cdot C_W \cdot \phi - C_g - C_{rh}$$

Where λ is the decay for secium-137 (s^{-1}), κ is the irreversible adsorption rate (s^{-1}), Φ is the porosity (Qb,Q=0.4, Qw=0.6), C_g is the concentration on to soil surface

Concentration of cesium-137 in the river channel as activity is transported downstream cesium-137 according to:

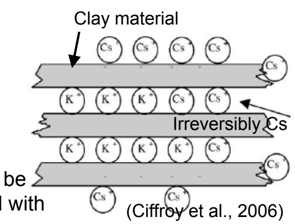
$$C_{W(x)} = C_{W(x=0)^{e^{-\beta x}}}$$

where β is 6.94 ×10^{-4} (m^{-1}). The characteristics length for cesium-137 adsorption, 1/β is 1440m.

The plume is well mixed across the river, the total cesium-137concentration will be given by:

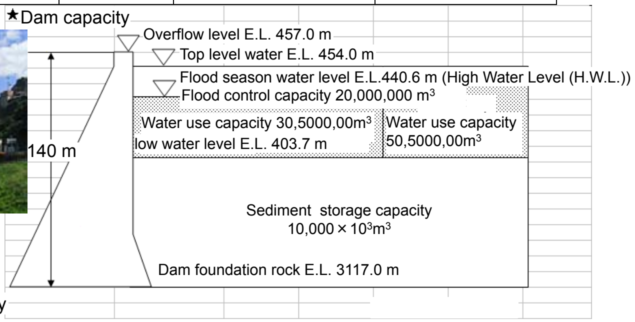
$$C_g' = \rho(1-\phi)$$

where A is the cross-sectional area of the river. This activity will be partitioned between that in the water phase and that associated with suspended sediments.



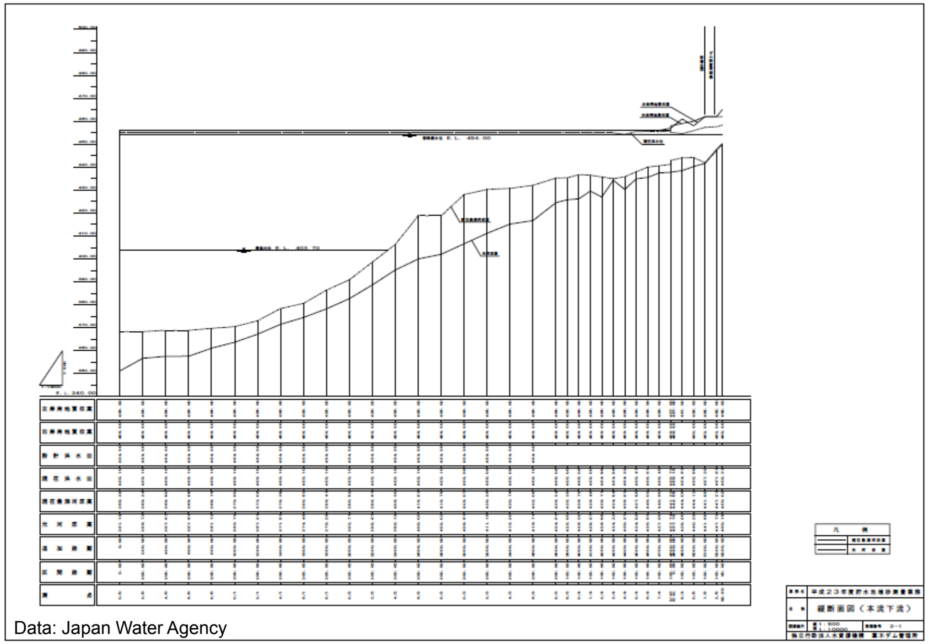
Case study of Kusaki Dam basin: calculation parameter, boundary condition and internal variable

Category	Original data	Material	Study area
River survey	1975 and 1998	Vertical section Cross section	Dam site – 0.0k - 5.2k Watarase R. 82.8k – 84k
Designed flood		Design flood wave form	
Water and Sediemtnt Inflow	1975 - 2012	Temporal inflow data	
Water discharge & Sediemnt discharge		Design flood wave form Provisory operation	
Sediment inflow	1998	Specific sediment yield Suspended	Kusaki Dam site (Catchment area: 253.3km2)
Wash load con.	1982, T8210	sedimentation ratio	Sawakiiresi site



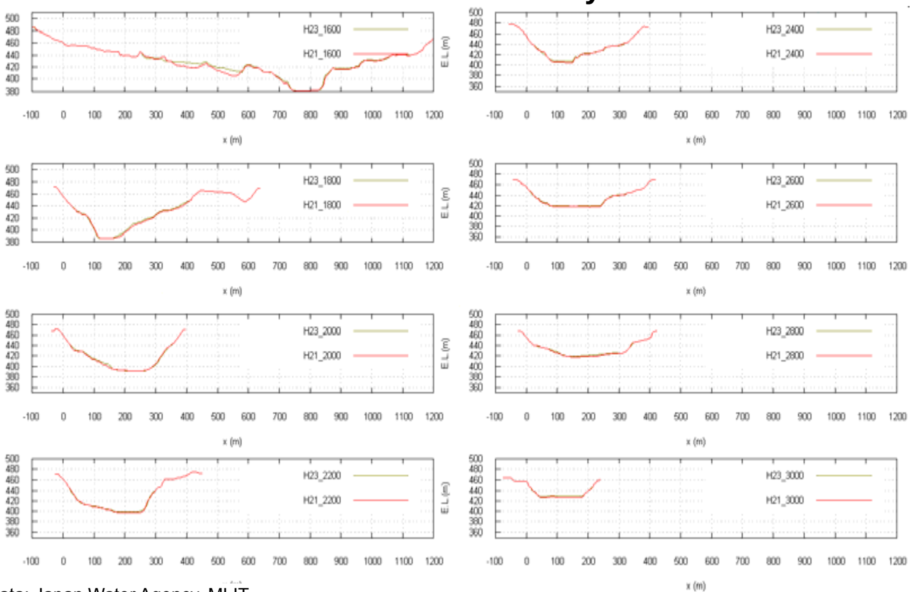
Data: Japan Water Agency

●Vertical sectional river survey data (1980-2011)



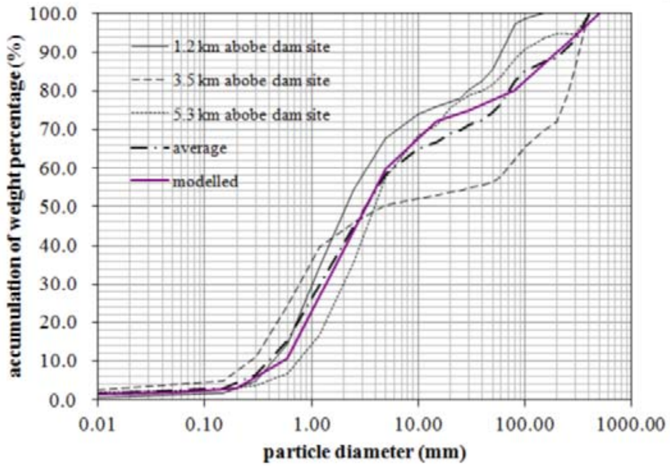
Data: Japan Water Agency

●Cross sectional geomorphology from river survey



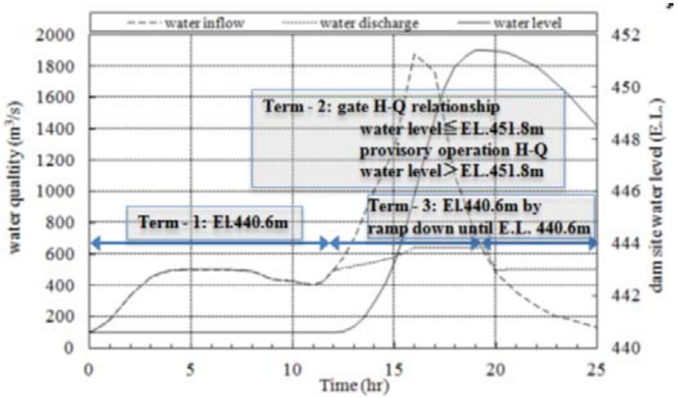
Data: Japan Water Agency, MLIT

●particle-size distribution of stream–bed material



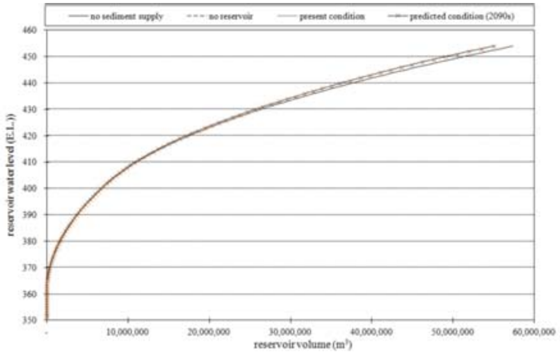
The particle-size distribution of stream-bed material. Data are from the Japan Water Agency (JWA) and the Hokuriku Regional Bureau of the Ministry of Land, Infrastructure and Transport (MLIT).

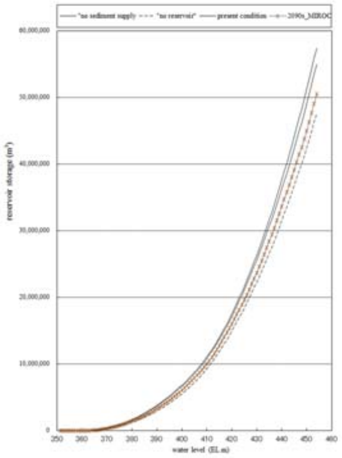
The regulation of the reservoir operation.



The regulation of the reservoir operation. Data are from the Japan Water Agency (JWA) and the Kanto Regional Bureau of the Ministry of Land, Infrastructure and Transport (MLIT).

● Relationship between the water level, reservoir storage at the dam site and the reservoi current and projected conditions.





・The agreement of water level and storage capacity experimental result indicates that the model was validated very well.
・The model used in this study also showed a limited ability to express incorporating the effects of complex phenomena occurring flood and the flood control by dam operation.

The relationship between the water level at dam-site and the reservoir volume for the present conditions and the future projection.

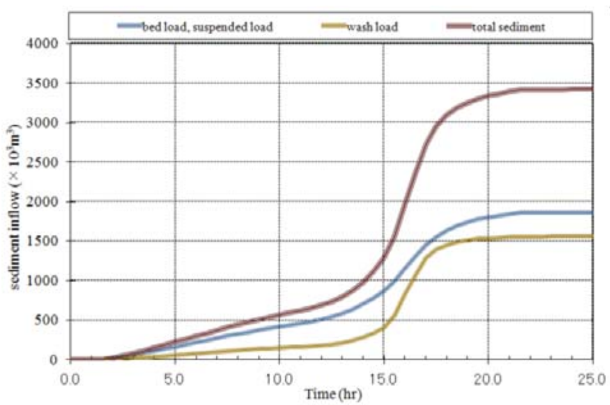
●boundary condition for the dam operation of Kusaki-Dam

The calculation condition was obtained by the regional dam regulation (JWA).

- Flood wave --- Designed flood wave as 100 years return period
- Initial water level --- E.L. 440.6 m (high water level (H.W.L))
- Dam regulation

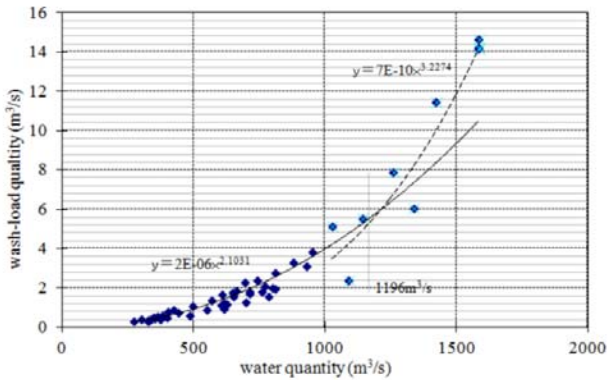
1. Preliminary operation
   Term 1: water inflow < 500 m³/s, water level = E.L. 440.6 m (inflow =discharge))
   ⇒E.L. 440.6 m
2. Flooding times
   Term 2: water inflow ≧ 500m³/s, reservoir water level :
   ≦ EL.451.8 m; maximum discharge=640 m³/s by using gate H-Q
3. Extreme flooding times
   Term 3: water inflow ＜ 500 m³/s; water level = EL.440.6 m;
   discharge = 500 m³/s as steady flow with ramp down until E.L.440.6 m.
4. Water reducing operation: inflow < 500m³/s, water level > E.L. 440.6 m
   ⇒maximum discharge = 500.0 m³/s
5. Normal operation
   ⇒water level < E.L. 440.6

● The regulation of sediment inflow for Kusaki-dam.



The regulation of sediment inflow for Kusaki-dam. Data are from the Japan Water Agency (JWA) and the Kanto Regional Bureau of the Ministry of Land, Infrastructure and Transport (MLIT).

●The relationship of washed sediment and water flow in the Kusaki Dam

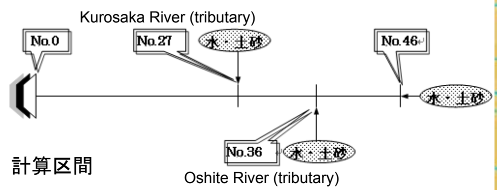


The relationship between wash-load quantity and the water quantity for Kusaki-dam based on Egiazaroff, 1965, and Ashida and Michiue, 1972. Data are from the Water Agency (JWA) and the Ministry of Land, Infrastructure and Transport (MLIT).

●Modelling components considered in the catchment framework for Kusaki Dam basin

Conceptual diagram

Sediment transport model of Catchment Simulator was applied to the Kusaki Dam basin , a tributary basin of the Tone River, Japan. Bottom figure provides in formation on the Kusaki Dam basin, which has a catchment area of 254 km2 and main water course length of 107km (6.4km). The model incorporates the Watarase River as main channel, Kuraosaka River and Oshite River as tributary.



Calculation distance: Dam site (0.0k) ～ Upstream end (6.4k)
Total: crosection: 46

●Dam sedimentation's condition (selected 13 terrain)

＜参考＞ 放射性セシウム濃度ごと(500Bq/kg)の延べ地点数 ( )内は前回調査

	500 以下	501 −1,000	1,001 −1,500	1,501 −2,000	2,001 −2,500	2,501 −3,000	3,000 以上	合計
河川	53 (55)	1 (2)	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)	55 (57)
湖沼・水源地	9 (13)	6 (9)	2 (5)	2 (1)	2 (2)	0 (2)	1 (4)	22 (36)

約5000 Bq/kg (2012年12月)

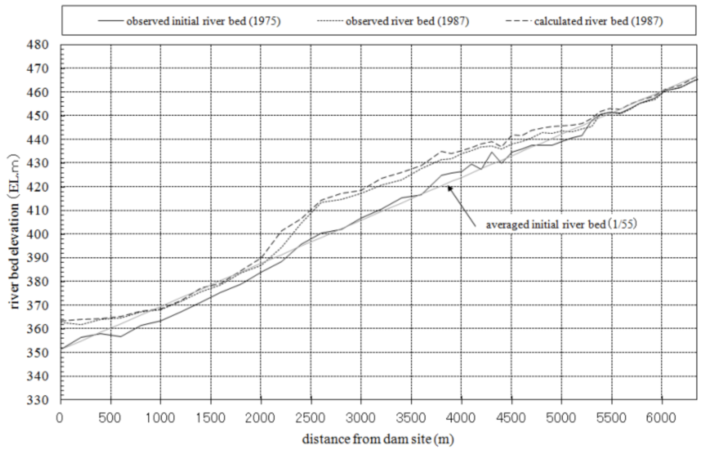
約2500 Bq/kg (2012年12月)

放射性物質	濃度(Bq／kg)	
放射性セシウム (セシウム134, 137)	肥料・土壌改良資材・培土・家畜用敷料	400
	牛, 馬用飼料*1	100
	豚用飼料*2	80
	家きん用飼料*2	160
	養殖魚用飼料*3	40

*1粗飼料は水分含有量8割ベース, その他飼料は製品重量
*2製品重量, ただし粗飼料は水分含有量8割ベース
*3製品重量

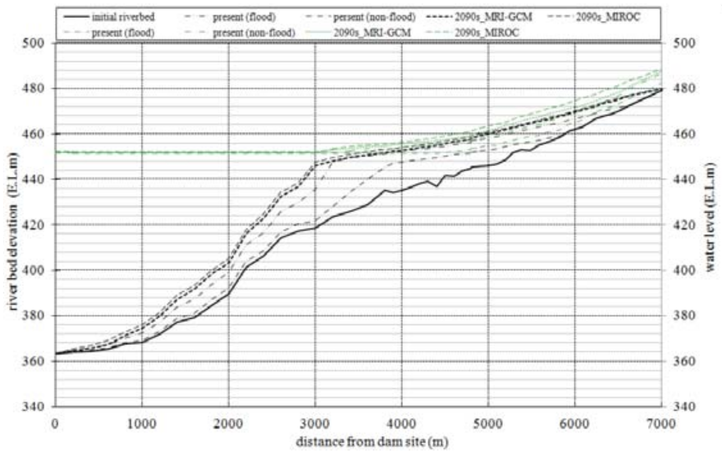
(MEXT, 2012)

●A vertical section of the riverbed variation. Data are from the Japan Water Agency (JWA) and the Ministry of Land, Infrastructure and Transport (MLIT).



・The agreement of sedimentation form, flux with experimental result indicates that the model was validated.
・The model used in this study also showed a limited ability to express the complex phenomena occurring the sediment control dam.

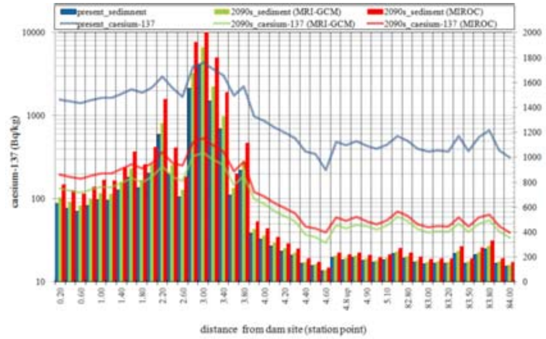
● A vertical section of the riverbed variation and current and projected water levels.

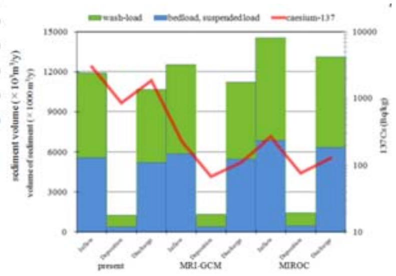


Although the form of delta formation is clear in the present condition, but the predicted future tendency is extended to the reservoir front comparatively gently-sloping due to increasing fine grain such as suspended load and wash-load.

Data are from the Japan Water Agency (JWA) and the Ministry of Land, Infrastructure and Transport (MLIT).

● Long-term variation of caesium-137 concentrations and the sediment volume for current and simplefied projected condition.





The amount of their cesium-137 discharge was approximately 116.5 Bq/kg for MRI-GCM scenario and 135.9 Bq/kg for MIROC scenario. The comparison of cesium-137 deposition ratio with present is 79.8.1%－82.0% decreased

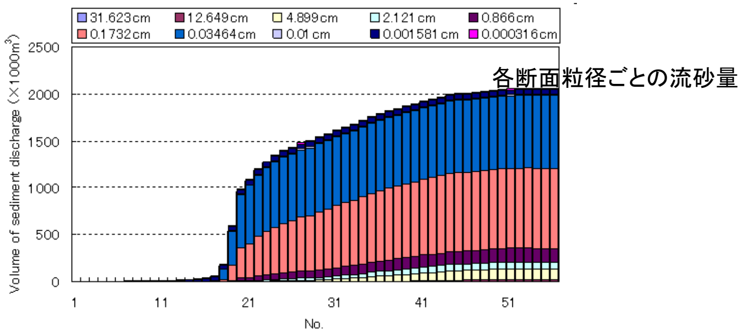
The dataset was partially provided by the National Institute for Environmental Studies and Japan Water Agency.

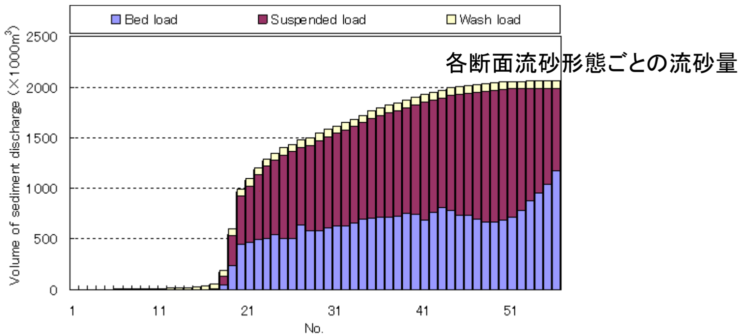
第１表　草木貯水池における堆砂量の経年変化

測定年度（昭和）	堆砂量（千m³）（期間）	（累計）	期間内最大流量（m³/s）
52	90	90	490
53	200	290	820
54	170	460	1, 100
55	90	550	160
56	560	1, 110	1, 200
57	870	1, 980	1, 600
58	90	2, 070	710

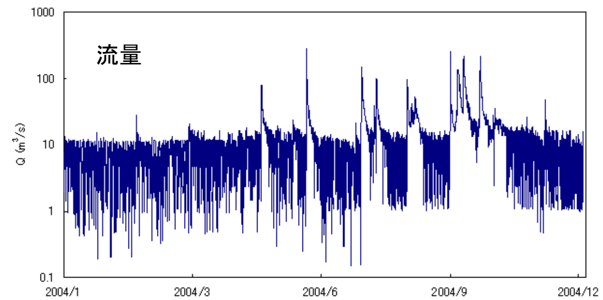
(池田ら、1985)

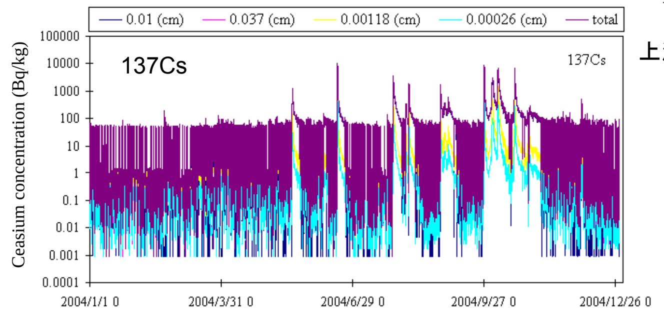
草木ダム





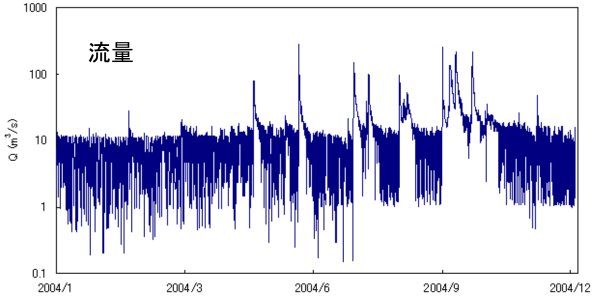
草木ダム

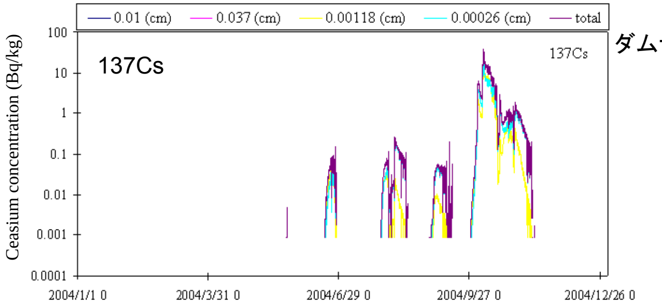




上流域

草木ダム

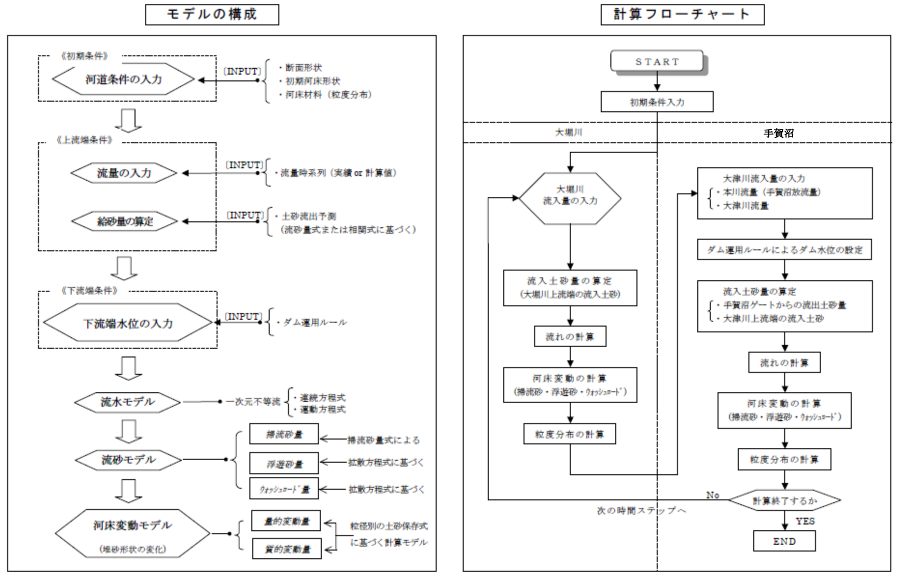




ダムサイト

手賀沼におけるモデル開発

〈 モデルの構成と計算フロー 〉

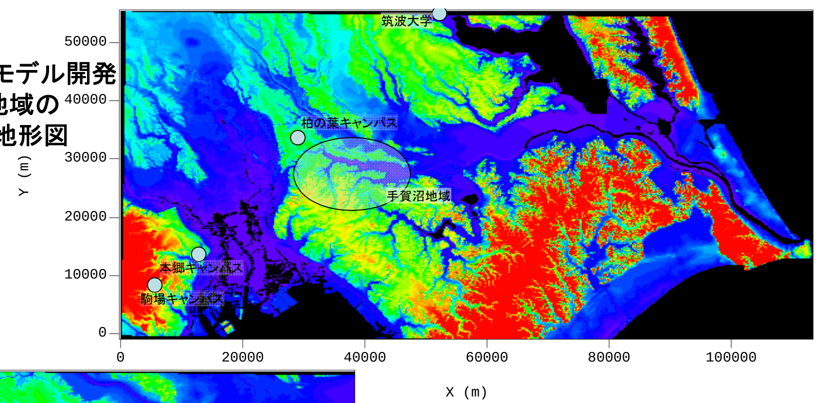


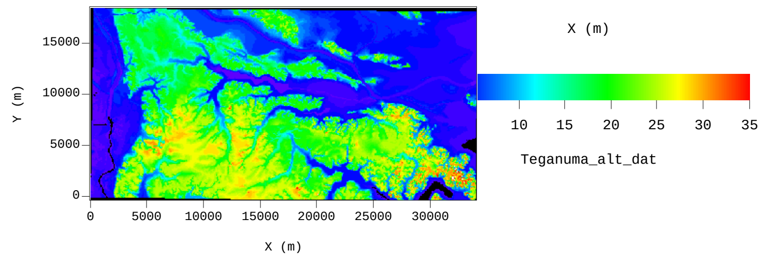
手賀沼

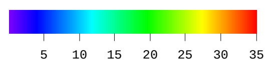
沼	面積（ha）		650
	周囲（km）		38.0
	水深	平均（m）	0.86
		最大（m）	3.8
	容量（千m³）		5,600
流域	指定地域内流域面積（ha）		14,398
	指定地域内流域人口（千人）		503
	流域市町村		7市（松戸市、柏市、流山市、我孫子市、鎌ヶ谷市、印西市、白井市）
	主要流入河川		大掘川、大津川、金山落など
利水	上水（千m³/年）		無
	工業用水（千m³/年）		無
	農業用水（千m³/年）		24,072（21年度）
	内水面漁業（t/年）		156（20年：印旛沼を含む）（主要魚種：コイ、フナ）

(末木先生,2011)

●手賀沼モデル開発
手賀沼地域の標高地形図

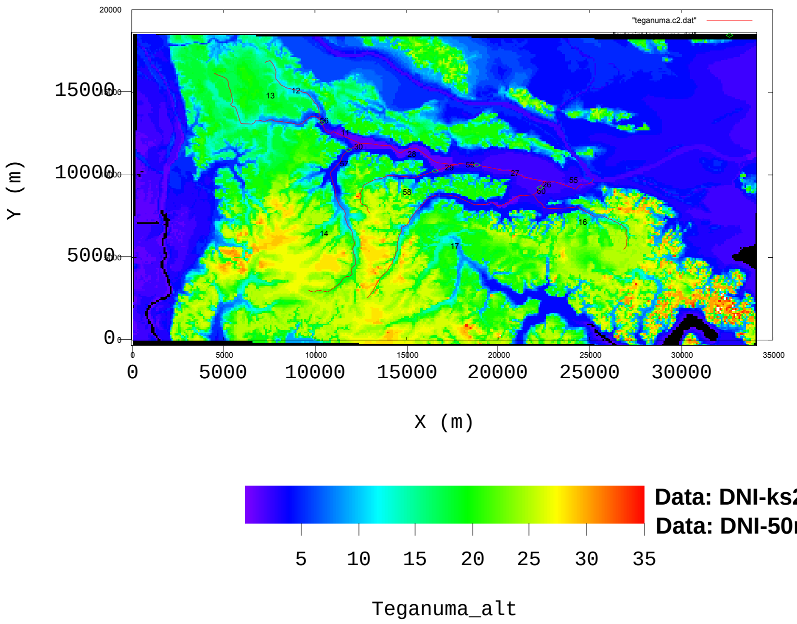






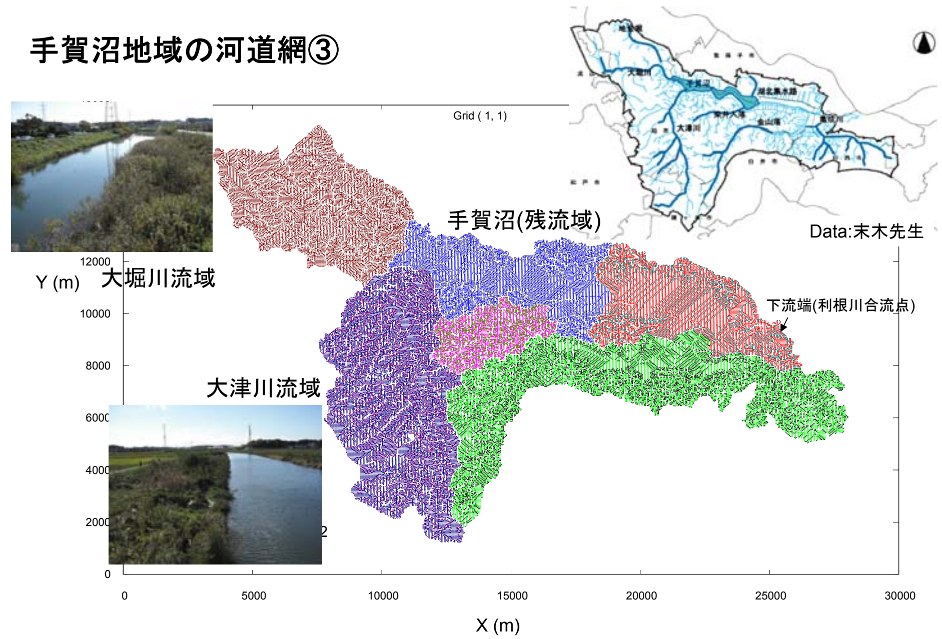
Data: DNI-50m

手賀沼地域の地形図及び河道網③



Data: DNI-ks271,ks272
Data: DNI-50m

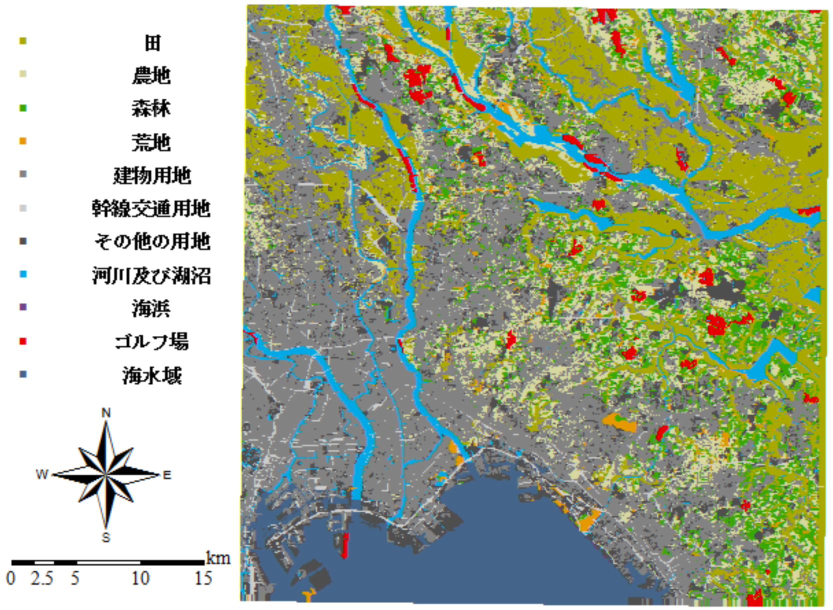
手賀沼地域の河道網③



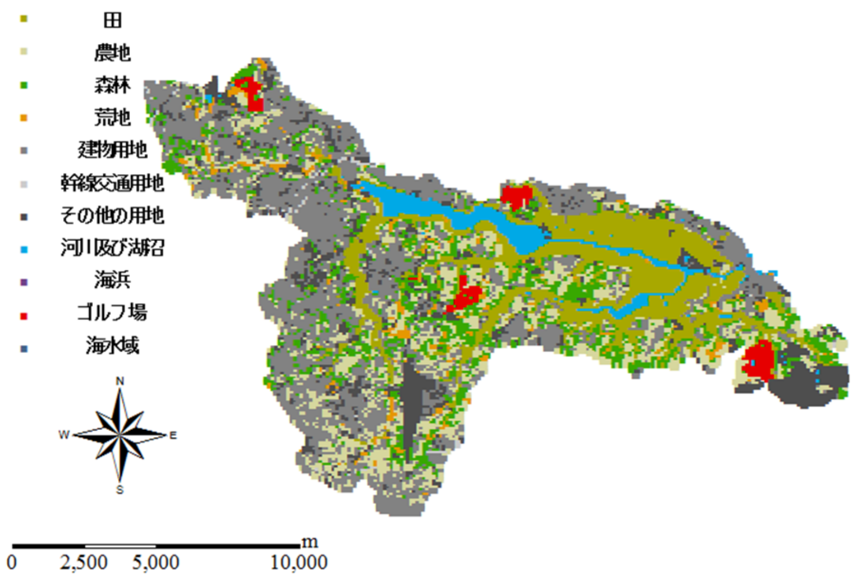
流域面積:148.85km^2

Data: DNI-ks271,ks272
Data: DNI-50m

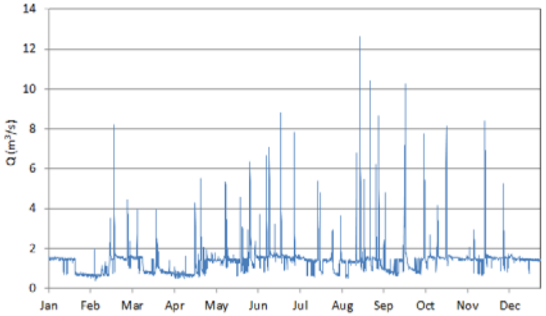
手賀沼地域の土地利用①



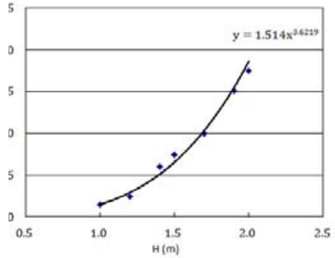
手賀沼地域の土地利用②



大堀川を対象とした土砂動態計算(昭和橋流量、H-Q式、標準断面図)

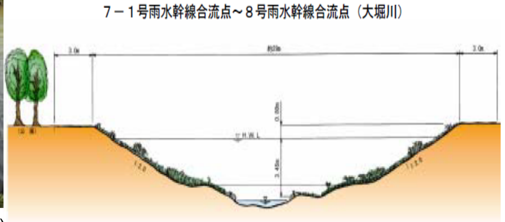


2011年、昭和橋流量



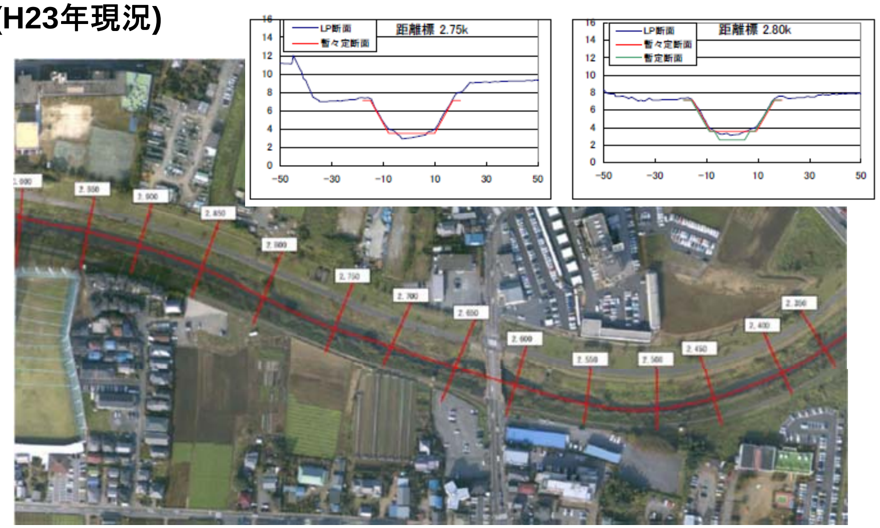
(酒井ら、2006)

浮遊砂のサンプリング(村上グループ)



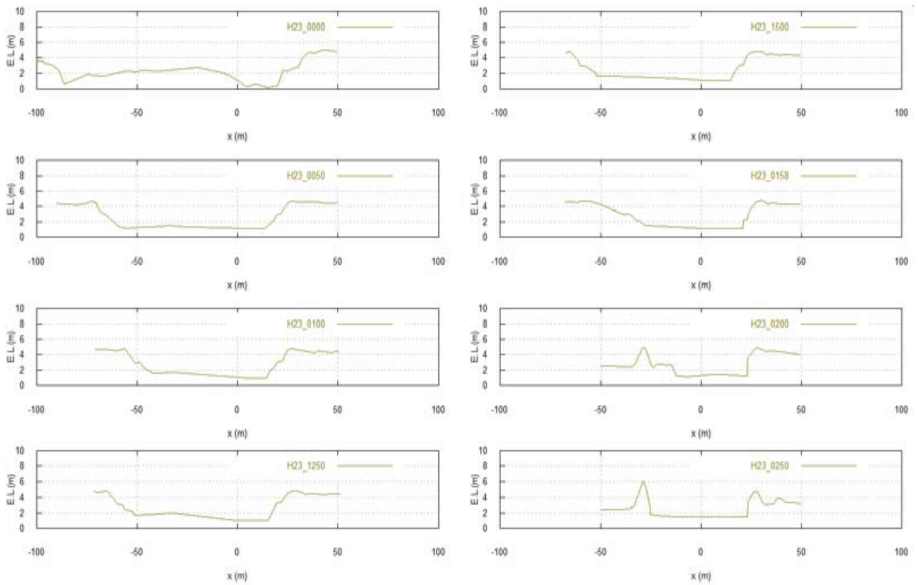
縦断勾配:
1/1500～
1/1300

大堀川におけるLP測量データ (H23年現況)

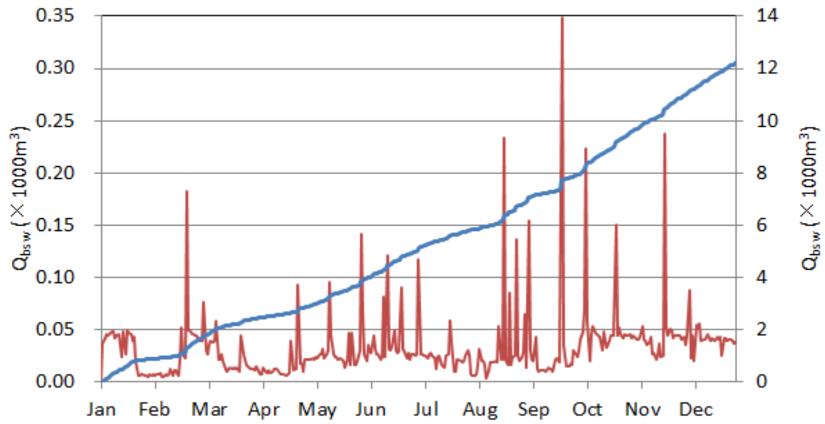


昨年度より測量が行なわれている。
・解像度：2 m、 精度：±30 cm
プラニメータを用いて現況(2011年)データを整理した。

大堀川におけるLP測量にもとづく現況河川横断 (2011年12月、0.00k-0.25k)

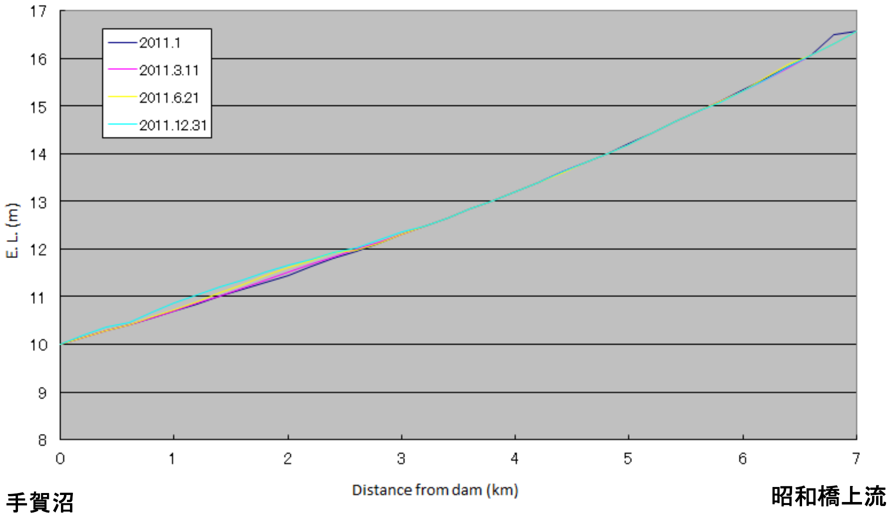


大堀川を対象とした土砂動態の連続解析結果



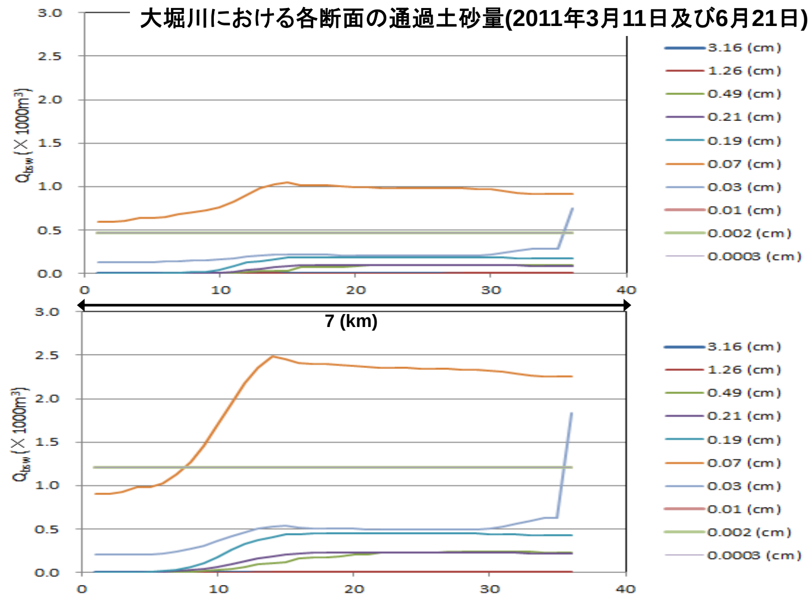
手賀沼への流入土砂量の試計算結果(2011年)

大堀川を対象とした土砂動態の連続解析結果



大堀川における河床形状の変化(2011年)

大堀川を対象とした土砂動態計算



出水時においては、微細粒子(SS)は河床に堆積しにくく、大部分はダムに流入している可能性がある。

● 今後の予定

- 末木G、芳村G、村上先生と緊密に連携する
- 大堀川での調査、検証 (ceasium-137、SS、水量など)
  Under way
- 草木ダムでの調査、検証 (ceasium-137、SS、水量など)
  Completed
- 蓬莱ダムでの調査、検証 (ceasium-137、SS、水量など)
  Under way