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REDUCTION OF SEDIMENT-LADEN WATER FROM CONSTRUCITON SITES INTO WATERWAYS:- A GOVERNMENT AND INDUSTRY APPROACH

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ABSTRACT: Water is a strategic resource for Singapore due to its small land mass and more than half of the mainland serves as catchment for raw water, including construction sites. Construction site typically involves earthworks and in conjunction with the frequent and intense rainstorm in Singapore, produce runoff of high turbidity due to suspended sediments. The resulting high concentration of suspended sediment in construction site runoff very often leads to aesthetically unpleasant reservoirs and potentially increases the treatment cost of raw water. To mitigate this, the local standard requires the discharged concentration of total suspended solids of construction runoff leaving a construction site to be less than 50mg/l which is a very high standard.

This paper will present, examine and discuss particular issues and practices of Singapore's construction industry in meeting this requirement. The focus will be on two areas: Government lead initiatives and industry practices. How the government agencies worked together with the industry professionals to develop a system to ensure meeting of the standard is discussed. In addition, the types of industry practices, including various Best Management Practice to reduce erosion in construction sites and implement effective sedimentation on construction sites are examined.

Keywords: Earth Control Measures, Erosion control, Sedimentation, Best Management Practices, Sustainability, Environment.

1. INTRODUCTION

The majority of construction projects involves earthworks and disturbs the ground which results in erosion of soil when it rains. Water from Singapore's frequent rainstorm carries the eroded sediment particles and if allowed to leave the construction site and be discharged into the waterways, it will lead to pollution of the environment commonly observed as brown coloured water in the public watercourse. In the early days, the main issue with silty water in public watercourse is mainly aesthetics and even though the legislation [1] stipulates that the total suspended solids concentration (TSS) of water leaving construction sites shall be less than 50mg/l, the construction industry did not pay much attention to it and the outcome was periodic reports of brown rivers followed by fines.

With the completion of the Marina Barrage in 2008 and construction of the Sungei Pungol/Serangoon dams, majority of urban areas in Singapore will serve as water catchment for raw water. It is thus clear that silty water due to sediment-laden water from construction sites finding its way into public watercourse will create unwanted environmental problem and increase the treatment cost of raw water. This paper discusses the initiatives of the government and industry stakeholder to solve this problem since 2002.

The Public Utilities Board (PUB) is Singapore's governmental agency in charge of water related issues and this is under its purview. It has carried out a review of the existing situation and observed the following:

a. Although the legislation is present, the discharge requirement is stringent but also vague in certain aspects.
b. The level of technology available to solve the problem is not clearly understood by the industry or easily available.
c. There is poor understanding / appreciation of the problem by the industry
d. No provisions for resources to tackle issues

The stage is thus set for PUB to tackle the problem with a new strategic approach and it has decided to employ the following four prong approaches:

a. Revise legislations
b. Bring in technology
c. Create awareness on need to reduce TSS concentration of construction runoff
d. Empowering and working closely with industry stakeholders

The following government agencies and industry organisations are vital stakeholders which have worked closely with PUB on this issue:

a. Institution of Engineers, Singapore (IES)
b. Association of Consulting Engineers, Singapore (ACES)
c. Singapore Contractors' Association Limited (SCAL)
d. Real Estate Developers' Association Singapore (REDAS)
e. Housing and Development Board (HDB)
f. National Parks Board (NParks)
g. Land Transport Authority (LTA)
h. Singapore Erosion Control Association (SECA)
i. Construction Industry Joint Committee (CIJC)

2. REVISION TO EXISTING LEGISATION

The existing legislation, through Regulation four of the Sewerage and Drainage Act and explicitly stated in the Code of Practice on Surface Water Drainage (CP) does not allow the TSS concentration of discharged construction runoff to be greater than 50mg/l.

PUB held a series of dialogues with representatives from IES, ACES and SCAL to find out their views on the existing regulation and noted the following view points:

a. The discharge standard is very stringent.
b. The CP is silent on severity of rainstorm which significantly affects the TSS concentration of construction runoff.
c. Currently no widely accepted system in the Industry to limit TSS concentration of construction runoff.

PUB noted the representatives' concern about the stringent discharge standard but it did not want to relax the requirement. However, it agreed that the current legislation was silent on the severity of rainstorm which leaves it open to interpretation on how sever a rainstorm to assume when designing a system to limit the TSS concentration in construction runoff. It also noted the comment on no widely accepted system to ensure construction runoff meet the required limit. With these information, PUB decided to revised the legislation to tackle the problem.

It has decided to revise the legislation to include the following:

a. Limit the severity of rainstorm for design to a two year return period when designing a system to ensure construction runoff meet the required limit.
b. Increase the severity of the fine and introduce the provision allowing for imposing of stop work order for extreme case of repeat offense by contractors.
c. Create a special class of Profession Engineers called Qualified Erosion Control Professionals (QECP) dedicated to designing a proper system to ensure construction runoff meet the required limit.

With the revised legislation, designing a system to limit the TSS concentration of construction runoff only needs to account for the maximum rainstorm intensity of two years return period and for rainstorm greater than two years return period, there is no requirement to meet the limit. However, to focus the mindset of the industry stakeholders to the severity of the problem, the fine for committing the offense has been increased and the possibility of imposing stop work order was legislated.

Lastly, the revised legislation calls for a special class of Professional Engineers, QECP, who will carry the responsibility of designing an adequate Erosion & Sedimentation Control (also known in Singapore as Earth Control Measures or ECM) plan for any construction site carrying out earthwork related activities for a contractor. The contractor has to submit the ECM plan to PUB and obtain approval prior to the commencement of earthworks. While it is the duty of the QECP to design an adequate ECM plan, he usually would not be on site full time and it is the responsibility of the contractor to implement, monitor and maintain the ECM plan at all times. To ensure that the QECPs continue to upgrade their knowledge, they are required to renew their QECP license annually and have to satisfy the QECP committee that they have attended relevant ECM related activities in the past year.

In order to ensure a smooth implementation of mandatory submission of ECM plans by contractors as prepared by QECPs, a transition period of one year (from June 2006 to July 2007) was announced to the industry in 2006. During the transition stage, only Professional Engineers (need not be QECP) can design ECM plan for contractors to implement and maintain on construction sites to achieve the required TSS concentration limit for construction runoff.

3. BRING IN NEW TECHNOLOGY

The conventional type of ECM relying on silt fences and sedimentation traps and basins are inadequate to limit the TSS concentration value of construction runoff in Singapore's urban cityscape due to the lack of space and stringent requirements. The industry prior to 2002 was still trapped in the conventional way of designing and

implementing ECM on site and thus PUB decided to take the lead to introduce new technology to complement the conventional ECM methods to achieve a better result.

3.1 Basic treatment plant

Chemical and membrane treatment plants are compact machines able to treat influent of relatively high TSS concentration values (>10,000mg/l) down to less than 50mg/l. However, they are very seldom found in Singapore due to its very high cost and comparatively low treatment capacities (typically less than 100m^3/hr).

The approach taken by PUB was to gradually bring in suitable technology and the first silty water treatment plant (AquaSed: Hong Kong Productivity Council) was brought in by PUB in the early 2000 and used as a showcase to the industry on the possible technology available to treat silty water.

The cost of the treatment plant was relatively high then because it was a new comer but the objective of introducing available technology has been achieved. Within the next few years, the local industry started to develop their own version of treatment plant (both chemical treatment and membrane treatment) and sell them to contractors. With the gradual introduction of more players (selling treatment plants) the cost of these plants started to drop thus benefiting the owners and contractors. For illustration, the cost for a membrane type treatment plant with a capacity of 3m^3/hr is about S$ 3000.

3.2 Specialist treatment plant: Prototype

The basic treatment plant is very useful in a typical construction site but is not very practical in linear development works. Linear developments like roadworks construction, drainage construction and pipe laying oftentimes requires the earthworks to "proceed" together with the pace of construction and thus is not static. The basic treatment plant becomes disadvantaged unless it can also be mobile and moves with the pace of construction.

Thus a specialist treatment plant that is mobile and can move together with the pace of construction is needed. PUB worked with a local technology provider (Hyflux Ltd Singapore) to fabricate a prototype treatment plant mounted on a truck with its own flow meter and TSS concentration monitoring system. This specialist treatment plant can move to the required location to treat silty water and record the amount of treated water as well as the quality (TSS concentration value) of the treated water.

The advantage of measuring water treated offers the possibility of pay-as-you-treat for the end users and improves the flexibility for the construction industry. As usual, the initial cost for such specialist treatment plant would be high but with more players coming in or with more demand for such plants, it would gradual drop.

3.3 Continuous monitoring of treated water at discharge points

The traditional way of monitoring the quality of construction runoff is to take water samples and determine the concentration of total suspended particles in a laboratory. While this process is very accurate, it is very time consuming and not practical.

PUB is exploring using close circuit television (CCTV) technology and broadband wireless network to create a continuous monitoring system for all construction sites in Singapore. The concept is to attach a total suspended particle probe to monitor the quality of water discharged from a construction site and use broadband wireless network technology to broadcast the information to anyway within Singapore. At the same time, a CCTV camera can also be located near to the discharge point to monitor the colour of the water discharged and broadcasted similarly.

When this system takes off, the enforcement officers would not need to take samples when visiting sites so often and will be able to conduct random checks on any sites at any time. Warning signals can also be sent to construction personnel and enforcement officers instantly when problems occurs to allow immediate action to be taken.

PUB has already brought in suppliers of such systems and implemented it on their own construction (drainage related development) works and started to showcase such technology to the industry. As it is a relatively new initiative, the cost of such a system is still very high and PUB is currently working with selected project partners to implement such system. As usual, with the passage of time and introduction of more competition and demand, the cost will gradually reduce and getting all sites to be installed with such system may be eventually viable.

3.4 Encourage the setting up of Singapore Erosion Control Association

Both the industry stakeholders and PUB realized that as more specialized ECM products could be coming in for the next few years, there could be more suppliers coming into the picture. There should be an organization to represent these suppliers and coordinate their efforts to distribute these ECM products. As such, with the support of PUB and the industry stakeholders, the Singapore Erosion Control Association (SECA) was registered in 2005 and PUB initiates meeting with SECA members at least once a year to provide update on relevant issues and listen to feedback from the members.

Through SECA, there is a centralized organization

through which information related to ECM products can be obtained effectively. At the same time, any ECM initiatives taken by PUB or the industry stakeholders can also be made known to SECA so as to effectively disseminate to their members.

4. CREATE AWARENESS

In order to address the issue of lack of understanding and appreciation of the importance of limiting TSS concentration values, PUB decided to initiate a series of actions to create more awareness of the importance of ECM in limiting TSS values to the construction industry. A memorandum of understanding with IES was signed in 2004 which lead to formation of the Erosion Control Group in IES and other positive actions and illustrated in the next subsections.

4.1 Erosion Control Group, IES

PUB while having dialogue with IES and ACES suggested forming an Erosion Control Group (ECG) and parking this ECG group within IES. The objective of ECIG is to promote ECM through organizing seminars, workshops, site visits and related activities. The original members of this group included Engineers from IES, ACES and PUB but it has since included representatives from other government agencies (LTA, HDB and NParks) to promote more effective coordination of ECM activities among the different stakeholders.

Over the years, ECIG has been actively working with the industry to organize training programmes, seminars and workshops to promote ECM awareness and have recently begun to conduct training programmes for QECP for their continuous upgrading of knowledge and renewal of license. For example, Prof Y.M Chew [2] and Ms. Jernice Kew Hui Ling [3] were invited to present in IES-PUB seminar 2004 and Workshop on ECM in 2009 respectively. A series of workshops on how to monitor TSS concentration effectively were conducted in 2008/2009 and there will be a series of workshops on how to design, implement and maintain turbidity curtains for earthworks near watercourse in the later part of 2009.

4.2 National seminars and conferences

To achieve a wider outreach, PUB also organizes large scale seminars (approximately once every two years) with other organizations like CIJC to promote ECM. For example Er. Leong Kwok Wing [4] gave a very informative presentation in the CIJC-PUB 2005 seminar. The latest ECM seminar is coming in June 2009 and would be graced by the Parliamentary Secretary for the Ministry of Environment, Singapore. Such national seminar normally attracts a large crowd of participants include all rank and file and provides a good opportunity for PUB to showcase the latest ECM technology and policies. The ECM product suppliers also make use of the occasion to set up booths to showcase and display their products.

PUB also organized an International Environment and Water Conference in 2007 and had invited renowned speakers like Dr. Jerald S. Fifeld [5] to give presentation on ECM to the industry professionals in the Conference. It served as a good opportunity for the industry stakeholders to share and exchange knowledge with each other.

4.3 Website on ECM

The availability of technology has ensured that every established organization has its own website to reach out to its audience in the internet domain. PUB has decided to invest efforts to create a webpage [6] dedicated to ECM on its website. It serves as a repository for important information to allow any party to find out more about ECM issues. A list of the information available on the website is listed below.

a. Contact person for ECM in PUB
b. Lists of QECPs
c. Guidebook and general specifications on ECM
d. Sites with good ECM
e. Suppliers of ECM products

4.4 Encourage other Government Agencies to start internal ECM committees

As the public sector also oversee a large portion of project/construction development works in Singapore, PUB has reached out to them to promote awareness of ECM. Some of the government agencies include the Land Transport Authority (LTA), in charge of developing the road and railway systems in Singapore, the National Parks Board (NParks), in charge of development of garden, parks and park connectors in Singapore and the Housing Development Board (HDB), in charge of development of public housing in Singapore.

Through a series of dialogues and meetings, PUB has convinced these agencies to set up their own internal ECM committee to effectively promote proper ECM among the contractors undertaking their projects. For example, LTA's internal ECM committee has initiated its own ECM guidebook and has its own monetary system to reward contractors that have done well in ECM for their project while HDB has include the ECM record of contractors bidding for their projects in the tender stage.

5. WORKING WITH INDUSTRY STAKEHOLDERS

A PUB realized that getting the industry stakeholders involved in tackling the problem would be more effective than struggling with it on its own. Through working with the industry stakeholders and keeping them involved,

they will feel more empowered and thus be more receptive to initiate new ways of doing things more effectively.

5.1 Setting up the QECP committee and registry

Once the need for a special class of Professional Engineers (QECP) has been identified and preparations put in place for legislation, there is an urgent need to set up a committee to oversee the registration and administrative details for the QECPs. In agreement between IES, ACES and PUB, it was decided that there will be five permanent members in the QECP committee consisting of two representatives from IES and ACES and one representative from PUB. The committee meets once every two months to discuss the registration and renewal of licenses of QECPs and also deliberate on any QECP or ECM related issues.

5.2 Education of Professionals and Site Personnel

In order to ensure that a QECP applicant has sufficient knowledge on ECM to design and assist contractors to implement and maintain it, PUB and the industry stakeholders agreed that a dedicated professional course on ECM should be organized to impart the necessary knowledge. As such, the 1st run of the Professional Course on Erosion and Sedimentation Control (30 hours including quizzes and project assignment) was conducted in 2004 and taught by Professors from the local universities (National University of Singapore and Nanyang Technological University). This professional course was subsequently conducted once every year and is currently into its eight run.

As the QECP may not be on site all the time, it is pertinent to have a site supervisor skilled in ECM to assist the contractor to implement and maintain the ECM on site as all times. In order to ensure that there is a ready pool of site supervisors with adequate knowledge of ECM available to assist the contractors, IES together with PUB has organized a series of 1 day ECM workshop for site supervisors.

Both the Professional Course and the workshop are being certified by the Workforce Development Authority of Singapore as useful to industry and companies sending their staff to attend this workshop will be reimbursed with S$3.5 for every hour attended.

5.3 Working with private sector developer/owner

The Real Estate Developers' Association (REDAS) in Singapore plays a very active role in the development of the cityscape because the majority of the developers are members of this organization. In order to reduce duplication in efforts to spread the word on need for ECM in development works, PUB has decided to initiate dialogue sessions with REDAS.

The majority of the dialogue sessions focused on explaining the need for ECM to REDAS's members as well as the rationale for provision of ECM items in the Bill of Quantities for tendering purpose. After many sessions, the message is slowly getting through to the developers and there are more awareness on the need for ECM as well as the tendency to include items for ECM in Bill of Quantities for tendering.

In addition, PUB has created two categories of awards (Friend of Water and Watermark) to recognize individuals and companies that made significant efforts towards conversation of water and it also includes efforts in ECM related activity in construction sites. The recipients of these awards are announced in seminars and workshops and sometimes make it to the local newspaper which is a desirable form of positive publicity for contractors and developer/owners alike. PUB's ECM webpage also maintains records of recipients of the Friend of Water and Watermark awards for public viewing.

5.4 Working with Contractors

As part of its strategy to involve stakeholders and create awareness among the contractors, PUB has worked with SCAL to produce the first ECM guidebook in Singapore. This guidebook explains the rationale behind ECM and gives examples of good and bad ECM practices. It serves as the first step for a contractor looking at ECM for his construction site. The response to the first edition of the guidebook was very good and PUB together with IES and SCAL since launch the second edition of the guidebook with new information on ECM specifications and other useful details.

PUB also created a Water Efficiency Fund (WEF) which potentially allows a contractor to claim money from PUB for the amount of potable water saved in the course of construction work on site. This is a useful carrot for contractors because the quality of treated water (<50mg/l) is so good that it can be recycled for different types of washing on site which indirectly promotes sustainability in usage of water.

6. BEST MANAGEMENT PRACTICES

S A best management practice (BMP) refers generally to any program, procedural technique, method, operations, skills, measurement or device that prevents or removes or reduces erosion. It also refers to any measure that is implemented to protect water quality and reduce pollution from storm water runoff. In other reference materials, there is mention of Best Available Technology (BAT) which refers similarly to providing suitable solutions to problems related to erosion and pollution prevention.

6.1 Provision of ECM items in Bill of Quantities

for tender

One of the most critical BMP is provision of budget for achieving proper ECM on site and thus limiting TSS concentration of construction runoff. Without a budget, there would not be any effectively designed ECM plan and the contractor will not have resources to implement any ECM or maintain it.

Contractors normally tender for projects (be it private or public sector in Singapore) and the lowest tenderer has a very high chance of securing the project. Due to this, it is unlikely to expect any tenderer to automatically price in ECM items in the Bill of Quantities in a tender document and once the tendered project is secured, the contractor would end up having insufficient budget for designing, implementing and maintaining proper ECM on site which leads to TSS problems.

In order to initiate changes in the industry, PUB has revised tender documents for contractors bidding to secure drainage related development projects under its purview. It has included detailed specifications in its contract document and allowed for ECM items in its Bill of Quantities for contractors to tender. This provides a level platform for all tenderers to put in a reasonable amount for ECM items and thus the winning contractor will have a budget to design, implement and maintain proper ECM on his construction site.

The initial form of ECM items in the Bill of Quantities is a lump sum item but PUB is gradually changing the format from a lump sum item to more specific categorization (i.e. silt fence in per metre run).

The other government agencies (LTA, NParks, HDB etc) are slowly catching on and introducing ECM items in Bill of Quantities for contractors to price in their tender.

With the lead taken by the public sector, it is a matter of time before the private sector will follow the lead and include ECM items for tendering.

6.2 Treatment plant and adequate storage volume

Another effective BMP that forms the armour of the ECM plan to battle TSS problem is ensuring a balance between the capacity of the treatment plant and storage volume for silty water on site.

There is not enough space in a typical construction site for accommodating an effective sedimentation pond because the silt and clay particles requires too long a time and length to settle. It is a certainty for the majority of construction sites to install treatment plant (either a chemical or membrane treatment plan) and the capacity of a typical treatment plant ranges from 3-100m^3/hr. For a typical 2 years' return period rainstorm (roughly resulting in 60mm of rain over 1 hour) and assuming a typical construction site area of 1 hectare, the total amount of runoff could be up to (0.06*0.5*10,000) 300m^3. It can be seen that even with a treatment plant capacity of 100m^3/hr, there must still be a 200m^3 storage tank/pond to hold the remaining runoff for subsequent treatment prior to discharge offsite.

A good BMP will ensure a balance between the capacity of treatment plant and storage volume so as to minimize cost and space. The QECP will be in the best position to advise the contractor on this in his ECM plan.

6.3 Perimeter cutoff drains

Perimeter cutoff drains are critical BMP in a ECM plan because they prevent silty water from leaving the construction sites indiscriminately and instead channel the silty water to the designated area where it could be treated properly and discharged or even reused. In addition, if designed properly, perimeter drains can also be used as a temporary storage volume to contain silty water while buying time for the treatment plant to complete treating all the silty water.

6.4 Phased construction

Phased construction is an encouraged BMP because phased construction leads to a greater reduction in exposed bare earth surfaces at any one time and there will be lesser potential for erosion of soil. This requires the QECP to work closely with the contractor during the initial stage because once the contractor decides on a certain construction approach and planned accordingly, it would be very difficult for the QECP to come in and propose an ECM plan which includes phased construction but runs counter to the contractor's desired approach. In addition, phased construction generally leads to longer construction duration and the developer/owner needs to understand and accepts this fact in order for this BMP to be possible.

6.5 Maintenance regime for ECM

The initial ECM plan as designed by the QECP is usually implemented properly by the contractor and works perfectly during the first few months. However, with the passage of time, the ECM will begin to break down (silt fence tearing, treatment plant efficiency dropping etc). As ECM does not rank highly in the contractor's list of priority (quality of work, schedule of work completed, budget monitoring and safety of work), there may not be sufficient attention to monitor and maintain ECM on sites. This will lead to a gradual deterioration of ECM and may lead to TSS problems. Thus it is a good BMP to regularly monitoring, inspect and maintain the ECMs on site.

7. CONCLUSION

Prior to 2002 there was very little interest from the

industry stakeholders to limit the TSS concentration of construction runoff in Singapore even though tough discharge limits were always present. However, with more awareness on environmental sustainability and the creation of Marina Barrage and damming of Sungei Pungol / Sungei Serangoon to create urban water catchement, the issue of silty water becomes more than an eye sore as it potentially pollutes the environment, increase cost of treating raw water and leads to bad public image.

The government agency, PUB conducted an environmental scan and discovered that the root cause of silty water discharges (i.e. TSS concentration of water discharged exceeding regulatory limit) are four fold, namely unclear details on certain parts of the legislation, lack of technology and knowledge handle the problem, insufficient awareness of problem and inadequate resources to tackle the problem.

PUB revised the current legislation to strengthen its interpretation and also increased penalties to let the industry stakeholders understand the seriousness of the issue. It worked with them to legalize a special class of professionals (QECP) to carry out design of an effective ECM plan for the contractor to implement and maintain on construction sites to solve the problem. It also put in place a structure for this QECP system by setting up a committee to administer the QECP and requiring them to attend a minimum amount of ECM related training in order to apply for renewal of the annual QECP license.

To promote awareness and upgrade the knowledge on ECM which is vital to limit the TSS concentration of construction runoff, PUB worked with the Industry Stakeholders to conduct training courses for QECP and a certification course for site supervisors on ECM. It also organizes seminar, workshops and conferences for all parties on regular basis. It also encourages the industry stakeholders to form ECM committees to focus more attention on ECMs as well as maintain a website on ECM matters.

The technology gap is plugged gradually by PUB's initiative to bring in treatment plants initially to showcase and then encouraging the local industry suppliers to bring in or fabricate their own plants. It continues to lead the technology charge by introducing mobile treatment plants and CCTV/internet monitoring.

Finally, the issue of inadequate resources for ECM is tackled by taking initiatives to make provisions in contract documents for contractors to price in ECM items during the tender and encourage other government agencies and the bigger private developers/owners to do the same. It also started an initiative to allow contractor to claim back money by recycling treated construction runoff and giving positive publicity by handling out awards to deserving contractors and owners/developers that have put in efforts to design, implement and maintain good ECM on site to limit the TSS concentration of construction runoff.

The industry on its part also moved forward to embrace the changes in legislation, with the QECPs designing practical ECM plans and contractors implementing and maintaining them properly. Some of the essential BMPs that form the ECM plan were also briefly discussed, including the need to ensure provision for ECM for contractors to tender, ensuring a good balance between site storage and treatment, providing perimeter cutoff drain, phased construction and importance of regular maintenance of the ECM on site.

It is hoped that this paper has provided an insight to how the government and industry stakeholders can come together to work out solutions to a long standing problem on controlling TSS concentration of construction runoff. In addition, some important site practices (BMPs) were introduced to illustrate what can be done to reduce the TSS concentration of construction runoff.

REFERENCES

[1] Working Committee, "*Code of Practice on Surface Water Drainage*", 5th Edition, Mar 2000 PUB.
[2] Chiew, Y. M. (2004).General view of erosion and its significance. *IES-PUB seminar proceedings*.
[3] Jernice H.L. Kew. (2009) ECM Initiatives taken by LTA, *IES-PUB Workshop on ECM proceedings*.
[4] Leong K.W. (2005) A pictorial visit of international practices on erosion and sedimentation practices. *CIJC-PUB seminar proceedings*.
[5] Fifeld J. S. (2007) Advance Sediment and Erosion Control: Notes and Worksheet. *International Environment and Water Conference 2007, proceedings of conference*.
[6] Earth Control Measures. Retrieved March 23, 2009, from PUB Web site: http://www.pub.gov.sg/ecm/Pages/default.aspx.