Technical Program

Risk Management

Sunday, June 14 1:30 PM

Chairs: M. Ryan, Schiavone, Secaucus, NJ
R. Goodfellow, Black & Veatch, Gaithersburg, MD

Hindsight Is 20/20 – Reverse Engineering Tunnel Risk Analyses: *L. Abramson,* Hatch Mott MacDonald, Pleasanton, CA

Performing risk analyses on tunnel projects has become common place and on many projects it is required from an owner or regulatory perspective. After the project is planned, designed and constructed, the data concerning identified risks, assumptions, costs, probabilities and mitigations is generally long forgotten and buried in some file somewhere. A study was performed comparing predicted risks versus actual events on several recently constructed tunnel projects. Probabilities and costs for selectively common risks on tunnel projects have been studied and re-evaluated. Conclusions are presented that can guide future projects and the veracity of the tunnel risk analyses performed.

Getting the Engineer's Estimate Right: *T. Martin, J. O'Carroll,* and *K. Caro,* Parsons Brinkerhoff, San Francisco, CA and *T. Peyton,* Parsons Brinkerhoff, New York, NY

Mega projects present unique challenges with regard to estimating costs. With such projects, which may span decades, these challenges often begin as soon as a project is conceived. The importance of having a sound, resource based estimate available early in the process cannot be overstated because it provides the basis for ongoing project decisions. For the final phase of providing an updated cost estimate, oftern while bidding by contractors is underway, the Engineer's Estimate (EE) must incorporate present market conditions; account for possible volatile material price swings; be based on actual labor and fringe costs; rely on meaningful productivity rates; and accommodate any recent technology advances while identifying and allowing for risk factors. This paper explains the benefits associated with consultants adopting a contractor's estimating approach when preparing the Engineer's Estimate on megaprojects like the vairous tunneling projects in New York City.

Transfer of a Project Risk Register from Design into Construction: Lessons Learned from WSSC Bi-County Water Tunnel Project: *R. Goodfellow* and *P. Headland,* Black & Veatch, Gaithersburg, MD

Many underground projects now include preparation of a Risk Register through planning and design as a tool for project and risk management. There is still significant discussion within the industry as to whether and how to best present the Risk Register through the bidding process and the construction phase of a project. While the ITIG Code of Practice for Risk Management of Tunnel Works recommends this approach of continuity in risk management procedures, it is silent on the specifics of how this should be achieved. This paper will explore the perceived benefits and dis-benefits of including the project Risk Register with bid documents; format and content that should be transferred and lessons learned using the case history of bidding and early construction phase of the Bi-County Water Tunnel in Montgomery County, MD.

The Delivery of Underground Construction Projects in the UK: A Review of Good Practice: *A. Alder* and *M. King,* Halcrow Group Ltd., London, UK

The aim of this paper is to provide an overview of details of good practice, from a United Kingdom perspective, in the development and implementation of major tunnel and underground infrastructure projects. In doing so, it draws on a broad base of project management theory. A central theme is that successful project delivery is dependent on detailed planning of the complete project delivery process, forming an effective team that works well together and the proper management of risk. The role of partnering in forming a strong project coalition is described. Particular emphasis is given to the intergration of design and construction, and the role of the designer throughout the construction phase. The implementation of risk management in the design and construction of tunnel works is discussed, and recommendations are made on how risk, value and constructability can be integrated in project delivery. Recent practice in project procurement, particularly in the use of innovative collaborative forms of contract are described, and details of particular provisions for joint management of risk and problem resolution are provided. Finally, the relevance of the ITIG Code of Practice for Risk Management of Tunnel Works to good practice in project delivery is highlighted throughout the paper.

Using Risk Analysis to Support Decision Making on the Central Subway Project: *J. O'Carroll* and *N. Berry,* Parsons Brinkerhoff, Las Mesa, CA and *A. Wong,* San Francisco Municipal Transportation Agency, San Francisco, CA

What decision making tools and methods are available to a project owner when there is no clear differentiator between construction alternatives? A team led by a joint venture of Parsons Brinckerhoff and PGH Wong Engineering (PB/Wong) has been providing preliminary engineering seervices to the San Francisco Municipal Transportation Agency (SFMTA). The SFMTA and PB/Wong team developed several alternative construction methods for the tunnels and stations of the San Francisco Central Subway Project, none of which could be judged clearly better than another using traditional approaches and metrics. The team employed a risk assessment and analysis frameworks as a means of comparative analysis, drawing upon the knowledge of industry experts in the geotechnical, tunneling and construction fields to assist in the effort. This paper presents the approach and results of a cost and schedule risk analysis for two such analyses designed to answer two different questions regarding the advisability of different construction approaches. These assessments paved the way for key decision making in the preliminary engineering phase of the project and formed the foundation for continuing risk management efforts on the project. The focus of this paper is primarily the first two stages of risk management – identification and assessment – and some of the organizational dynamic issues that arise in such efforts.

Short Tunnels = High Risk?: Pipeline Construction Involving Open-Cut and Tunnel Segments: *M. Gilbert* and *M. Schultz,* CDM Inc., Cambridge, MA

In the world of tunneling the glamour is in the large diameter, long tunnels, but perhaps the number of projects for small diameter and short length tunnels are greater and generally have higher risk factors. Reasons for these higher risks include both the "boiler plate" contract provisions used on these types of contracts, the technical specifications related to the tunnel work (versus the pipeline construction), the bid practices including measurement and payment and the construction. This paper reviews and comments on some of the key issues the authors have observed in recent major pipeline projects that involve a small percentage of tunneling footage of the total contract.

Difficult Ground

Monday, June 15 8:30 AM

Chairs: A. Liu, Hatch Mott MacDonald, San Jose, CA
B. Robinson; Traylor, San Diego, CA

Times Square Connection: Supporting the Cross Roads of the World: *V. Paterno,* Skanska, New York, NY and *R. Fonkalsrud,* Skanska, San Diego, CA

In December of 2007, a joint venture of J.F. Shea, Skanska and Schiavone referred to as S-311, was awarded a $1.15 billion contract to construct the running tunnels and station structures for the Number 7 Line Extension Project in New York City by the Metropolitan Transportation Authority Capital Construction (MTACC) and New York City Transit (NYCT). As part of the contract, a technically complex and critical connection of the new tunnel to the existing, operational 7 Line subway was required. This paper describes the innovative design approach that was conceived to carry out the underpinning and excavation works both within the east-west 7 Line subway tunnel and beneath the north-south, 4 track, 2 level Times Square Station for the A, C & E trains. This underpinning provided temporary support to the subway substructure as the grade of the tunnel invert was lowered up to 10 feet into the rock sub-grade to allow the future subway to pass under the basement of the world's busiest bus terminal.

Gibe II Tunnel Project – Ethiopia – 40 Bars of Mud Acting on the TBM Special Design Measures Implemented to Face One of the Most Difficult Events in the History of Tunneling: *A. DeBiase* and *R. Grandori,* SELI Spa, Rome, Italy; *P. Bertola,* Lombardi and *M. Scialpi,* SELI Spa, Rome, Italy

In October 2006, a 7 m Double Shield TBM, boring through very poor volcanic formations, was pushed back by fluid mud, which presence had not been detected during previous field investigations, due to the high covers characterizing the majority of the tunnel axis. The present work describes the investigations made to gain better knowledge of the conditions in front and all around the TBM, the special measures implemented, the exploratory and bypass tunnels excavated, the extraordinary occurrences came true during the execution of these tunnels, the drainage campaigns, the design of the chamber excavated to free the TBM, the dismounting and restarting of the TBM.

Design & Construction of the Lenihan Dam Outlet Tunnel and Shaft: *H. Desai,* Santa Clara Water District, Santa Clara, CA; *B. Mainer,* Drill Tech and Shoring, Antioch, CA; *M. Murray,* Hatch Mott MacDonald, Pleasanton, CA; and *S. Spreng,* Jacobs Assoc., San Francisco, CA

A damaged outlet pipe beneath Lenihan Dam has restricted reservoir discharges, severely constraining the owner's groundwater recharge program. The solution, a new outlet pipeline through the dam's right abutment, includes an approximately 12.2 m deep (40 ft. deep) shaft and 618.7 m long, 4.3 m diameter (2,030 ft. long, 14 ft. diameter) tunnel mined in Franciscan melange composed of hard blocks of rock and soft clayey matrix. Alternating roadheader with drill and blast operations and using steel ribs and shotcrete have proven a flexible combination for handling the variable ground conditions. Excavating the shaft and connecting it to the tunnel require lowering the reservoir for five months, during which time careful construction sequencing and use of a tunnel plug eliminate the risk of an uncontrolled discharge.

Daniel Island Surprise – Sand Lens Lurking in Cooper Marl Charleston, SC: *R. Brainard,* Black & Veatch, Kansas City, MO; *P. Smith,* Black & Veatch, Charleston, SC; and *L. Drolet,* Charleston Water System, Charleston, SC

Charleston Water System's Daniel Island Extension Tunnel, initially thought to be the simplest of the four replacement tunnels to design and build, became the most challenging after the discovery of an unexpected 30 ft. thick lens of sand in the normally consistent Cooper Marl while sinking a shaft on Daniel Island. This paper will explore the challenges involved with determining the extent of the unforeseen lens of sand, the accelerated boring program, and the redesign of the vertical alignment – keeping the alignment between the sand layer and the bottom of the Cooper River. It will describe how the challenges were overcome, and how the owner, engineer, and contractor were able to team together to achieve the desired results.

San Vincente Pipeline – Reach 4 W, 3, and 2: Case History: *M. Jatczak* and *B. Zernich,* Traylor Brothers Inc., Lakeside, CA; *S. Short,* Construction Tunneling Services, Auburn, WA; and *W. Monahan,* Traylor Brothers Inc., Lakeside, CA

The San Vincente Tunnel Project is an 11 mile water tunnel constructed for the San Diego County Water Authority. One of the many challenges of the project included tunneling a 22,000 ft. single heading tunnel on the western half of the job in varying geology using a 3.66 m (12 ft.) diameter open shield excavator or "digger shield." This paper will discuss the design considerations for the temporary liner, the tunneling, and ancillary equipment. It will also highlight the challenges faced while mining this geology, explain the methods implemented to drive this section of tunnel, and discuss the experiences while performing mechanized tunneling in an extensive and varied San Diego geology.

A Review of Tunneling Difficulties in Carbonate Sedimentary Rocks: *D.P. Richards,* Parsons Brinkerhoff, Denver, CO; T.W. Pennington, Parsons Brinkerhoff, New York, NY; *J.A. Fischer,* Geosciences Services, Bernardsville, NJ; and *G. Garcia,* GilCo Group Inc., Indianapolis, IN

Tunneling in carbonate sedimentary rocks such as limestones and dolomites can be difficult when solution channels or voids are anticipated. Addressing the risk aspects associated with these formations can be done effectively through the Geotechnical Baseline Report (GBR) by properly characterizing the ground and ensuring that the Owner's and the Contractor's interests are represented and protected. This paper presents a review of tunneling difficulties in these rocks and includes a review of site investigations, geologic characterization, and presentation in the GBR. Key construction issues are also discussed, including appropriate excavation technology, mechanisms of face support and groundwater control, and quantifying grout takes.

Las Vegas

Monday, June 15   8:30 AM

Chairs: M. Jensen, Southern Nevada Water, Las Vegas, NV
J. McDonald, Impregilo, Boulder City, NV

Design & Construction of Lake Mead Intake No. 3 Shafts and Tunnel: *J. Hurt,* Arup, New York, NY; J. McDonald, Vegas Tunnel Constructors, Las Vegas, NV; *G. Sherry,* Brierley Assoc., Littleton, CO; *A. McGinn,* Brierley Assoc., Liverpool, NY; and *L. Piek,* Arup, San Francisco, CA

The entire scope of new facilities for Lake Mead Intake No. 3 includes a submerged intake structure, a deep tunnel beneath Lake Mead, a tunnel access shaft, Intake Pumping Station No. 3, and connections to an existing intake and the water treatment facility. This paper will describe the design and construction of the tunnel access shaft, the tunnel and the intake, with a focus on the access shaft which is nearing completion the most complete section of the work. The shaft is being sunk using drill-and-blast methods with the final lining placed as excavation proceeds. The shaft passes through a major fault zone, and extensive pre-excavation grouting for water controls is required for much of the depth of the shaft.

Project Delivery Selection for Southern Nevada's Lake Mead Intake No. 3 – Las Vegas, Nevada: *M. Feroz,* Parsons Water Infrastructure, Las Vegas, NV: *E. Moonin,* Southern Nevada Water Authority, Las Vegas, NV; and *J. McDonald,* Vegas Tunnel Constructors, Las Vegas, NV

Severe drought in the Colorado River Basin over the past 10 years has caused water levels to drop in Lake Mead by more than 110 feet. Lake Mead is the primary source of water supply for greater Las Vegas. Water from Lake Mead is accessed through two existing submerged intake shaft and tunnel systems. If the water levels continue to drop in the Lake, the Intake No. 1 will become inoperable. To sustain the current levels of water delivery to SNWA member agencies a third intake at a deeper depth in the Lake is required. The Lake Mead Intake No. 3 facilities will consist of an intake riser, a 15,500 foot long and 20 foot diameter tunnel, and approximately 600 foot deep access shaft. Hyperbaric interventions with pressures up to 17 bars may be required during the mining of the tunnel. Schedule is of utmost importance to build the Intake No. 3. In order to achieve this goal the Design-Build (D-B) delivery method was embraced for this project. The D-B contract was awarded for $447 million to Vegas Tunnel Constructors Joint Venture (Impregilo and S.A. Healy). The construction is currently under way with scheduled completion of December 2012.

Design and Subsurface Construction at Yucca Mountain, Nevada: *J. Beesley,* Bechtel SAIC Co., LLC, Las Vegas, NV and *J. Gonzalez,* U.S. Department of Energy, Las Vegas, NV

This paper discusses the design of the subsurface nuclear waste repository at Yucca Mountain, Nevada. Construction concepts for the subsurface facility are also reviewed. The subsurface facility design includes approximately 107 km (66.5 miles) of tunnels, most of which will be excavated with 5.5 m (18 ft.) and 7.62 m (25 ft.) tunnel boring machines. Design and construction concepts for the subsurface repository are based on the License Application that was submitted to the U.S. Nuclear Regulatory Commission by the U.S. Department of Energy on June 3, 2008.

Feasible Tunnel Construction Options for the Systems Conveyance and Operations Program Reach 3 Tunnel: *S.H. Choi,* Jacobs Assoc., Pasadena, CA; *S. Ball* and *S. Tokarz,* MWH Americas, Inc., Las Vegas, NV; and *J. Devlin,* Clean Water Coalition, Henderson, NV

The Systems Conveyance and Operations Program (SCOP) is being implemented to convey tertiary-treated effluent to Lake Mead near Las Vegas, Nevada. The Reach 3 Tunnel Project is part of SCOP. The tunnel's planned location along and across the Las Vegas Wash creates challenging tunneling conditions. A number of feasible excavation and intial support methods are being considered during the final design stage. This paper describes how the tunnel construction options were refined based on anticipated tunneling conditions and compatibility between tunnel excavation and initial support methods. A brief description of the most significant characteristics of the anticipated ground conditions is included for the purpose of discussion.

What Happens in Vegas: The Apex Tunnel Geologic Investigation: *A. Backstrom* and *J. Metcalf,* Kleinfelder, Las Vegas, NV and *S. McKelvie,* HDR Engineering, Inc., Pearl River, NY

The Apex Tunnel is part of the Southern Nevada Water Authority's proposed Clark, Lincoln, and White Pine Counties Groundwater Development Project. The project is intended to develop unused Nevada groundwater for meeting the water needs of Southern Nevada and would involve over 322 km (200 mi) of water transmission facilities. The Apex Tunnel, as currently conceived by ongoing planning and environmental analyses, would extend 2804 m (9,200 ft.) through a structurally complex terrain of Paleozoic carbonate rocks and younger basin fill deposits and will traverse both public and private lands. Several faults cross the tunnel study area, juxtaposing rocks of varying lithology and degree of folding, and creating intervals of differing rock conditions along the tunnel alignment. This paper discusses how the geotechnical program was developed to be flexible and allow for rapid implementation of revisions based on new knowledge that became available during program execution, resulting in more effective decision making and enhanced value from the geologic investigation during the planning phase of the project.

The Cost and Benefit of the Phase 2 Investigation for the Reach 4 Tunnel, How a Roll of the Dice Came Up Big in Las Vegas: *R. Brainard,* Black & Veatch, Kansas City, MO; *R. Johnsen,* University of Nevada Las Vegas, Las Vegas, NV; *J. Devlin,* Clean Water Coalition, Henderson, NV; *E. Smith,* University of Nevada Las Vegas, Las Vegas, NV; *T. Knox,* Black & Veatch, Kansas City, MO; *J. Werle,* Converse Consultants, Elko, NV; and *A. Noronha,* Black & Veatch, Kansas City, MO

The subsurface investigation for the Reach 4 Tunnel was expected to be completed in a single phase. This assumed that data from two nearby previous tunnels, combined with limited new subsurface information and surface mapping would be sufficient to characterize the rock behavior. Unforeseen rock conditions and complex faulting led to the recommendation for a second phase. This decision was not reached easily, as much of the follow-on work required helicopter support, and associated costs.

The second phase of drilling found significantly more variability that the first phase and led to a very different and better understanding of the geologic and geotechnical conditions, and rock characterization.

New Projects I

Monday, June 15 8:30 AM

Chairs: M. Fowler, Parsons Brinkerhoff, San Francisco, CA
T. O'Donnell, Kiewit, Portland, OR

Planning New Metro Subways – Los Angeles, California: *A. Elioff,* Parsons Brinkerhoff, Los Angeles, CA; *D. Perry*, MACTEC, Los Angeles, CA; *G. Roy,* LACMTA, Los Angeles, CA; and *P. Romo,* MACTEC, Los Angeles, CA

Success of the Gold Line Eastside Extension rail tunnels in Los Angeles has prompted Metro's planning for two new rail lines to include underground alternatives. The Westside Extension Transit Corridor alternatives include up to 17 miles of subway to be constructed in soft ground. The routes will require construction in Los Angeles' "Potential Methane Zone," not considered for subway construction until recently. Slurry face TBMs will likely be specified. The Regional Connector, through the downtown area, includes one underground alternative with 1.7 miles of tunnel as well as three underground stations in soft ground and rock. Challenges will include tunnel and station construction under narrow streets. This paper will describe the alternatives, planning, geologic conditions and tunneling concepts for both planning studies.

Slurry TBM Tunnel in Rock, The Modified Detroit River Outfall No. 2: *W. Hansmire,* Parsons Brinkerhoff, Detroit, MI; *P. Turner,* Detroit Water and Sewage Dept., Detroit, MI; *R. Shukla,* Detroit Water and Sewage Dept., Detroit, MI; *F. Mir,* Vinci Construction Grands Project, Montreal, Canada; and *P. Jafri,* Detroit Water and Sewage Dept., Detroit, MI

The Modified Detroit River Outfall No. 2 (MOD DRO-2) will discharge treated wastewater to the Detroit River. Construction of a 6.4 m diameter, 1.9 km long tunnel was halted in 2003 by flooding during tunneling with an open face hard rock TBM. A new design for a higher rock tunnel, a "Modified" design, was completed in 2007 and Notice to Proceed to the tunnel contractor was given in November 2008. Project duration is four years for completion of tunneling and start of outfall tunnel operation. This tunneling project has high groundwater pressure (5 bar), previous limestone rock of up to 140 MPa (20,000 psi) strength, and hydrogen sulphide in the groundwater. The new tunnel will be connecting to access shafts and outfall diffuser riser shafts previously built for the now-abandoned tunnel. The new tunnel design construction contract, and initial planning to use a pressurized-face (slurry) hard rock TBM are presented.

Port of Miami Tunnel Update – A View From Design Builder's Engineer: *W.P. Chen,* Jacobs Engineering Group, Boston, MA

Technical and non-technical challenges exist in each mega infrastructure project. It's no exception to the first US underground PPP Port of Miami Tunnel (POMT) project in Miami, FL. The POMT will connect two man-made islands, the Dodge and the Watson Islands, under the Biscayne Bay within highly porous limestone formation. Permeability as high as 0.1 cm/sec has been identified. Its 41 ft. outside diameter, if constructed, is the largest precast segment lining in the US. Besides its geological and hydrogeological challenges and risks, local community influence and impacts have controlled the fate of this project. This paper describes its tender design enhancements and the evolving of its slow advancement in resolving local community issues.

Design Considerations and Evaluation Process for a New Tunnel and Ocean Outfall Project: *S. Dubnewych and M. Torsiello,* Jacobs Assoc., Pasadena, CA; *J. Kaneshiro,* Parsons Corp. San Diego, CA; and *D. Haug,* Sanitation Districts of Los Angeles County, Whittier, CA

The Joint Water Pollution Control Plant, operated by the Sanitation Districts of Los Angeles County, treats wastewater generated by over three million people. A new tunnel and ocean outfall is being considered to meet future hydraulic demands and provide long-term redundancy for the Districts' existing tunnels, portions of which were constructed as early as the 1930's. The detailed process used to evaluate the feasibility of various tunnel and outfall locations is described. Challenges include a geologic profile with mixed face and squeezing ground conditions; high water pressures; active fault crossings; gassy and contaminated ground conditions; and liquefaction, slope stability, and lateral spreading concerns in the area of the riser and diffusers.

MBTA Silver Line Phase III – Completes Boston's Newest Transit Line: *G. Yates,* AECOM USA, Boston, MA; *M. Ainsley,* Massachusetts Bay Transit Authority, Jamaica Plain, MA; and *W. Gallagher,* URS Corp, Boston, MA

The Silver Line is a BRT line and is Boston's newest transit line. Phase III will connect existing Phase I and Phase II segments of the line via one-mile long twin mined tunnels from a connection at South Station to a portal near the Back Bay. The tunnels will be mined deep below the surface through some very congested areas of the city. Major cut & cover stations will be constructed providing for the Line's connection to Orange and Green Lines. This paper will describe the preliminary design that is underway, overall project schedule, subsurface conditions along the alignment, anticipated construction methods, and impacts on the surrounding areas. The unique configuration of the project and the geotechnical conditions will be discussed.

TBM Case Histories I

Monday, June 15 8:30 AM

Chairs: S. Oginski, J.F. Shea, New York, NY
C. Christensen, J.F. Shea, Pleasant, NY

TBM Tunneling at the Ashlu Hydropower Project, Squamish, BC: *S. Moalli* and S. Redmond, Frontier Kemper Constructors ULC, Squamish, Canada; *D. Brox, P. Procter, D. Jezek,* and *M. Kraan,* Hatch Mott MacDonald, Vancouver, Canada; and *R. Blanchet* and *R. Kulka,* Innergex Renewable Energy Inc., Vancouver, Canada

The Ashlu Creek Hydro-electric project, located north of Squamish, BC, at the confluence of Ashlu Creek and the Squamish River, comprises a 49 MW run-of-river project and features a 4.08 m diameter, 4.4 km power tunnel and a 128 m deep drop shaft. The Ashlu Creek Hydro-electric project is being developed by Innergex under Ashlu Creek Investments Limited. Site civil works are being completed by Ledcor CMI of Vancouver with tunnel construction by Frontier Kemper Constructors ULC under a lump sum design-build contract. Site works got underway in September 2006 with the construction of the tunnel portal and laydown area. These site works required rock slope stabilization over a 50 m rock slope to secure the laydown areas as well as the construction of a tail track muck tipping station and structural wall to facilitate TBM excavation and spoil removal. Starter tunnel construction commenced in early 2007 and TBM tunneling started in the late spring of 2007 and is planned to continue until early 2009. The power tunnel is being excavated using a 1200 kW Wirth open-type hard rock TBM dressed with 31 - 17" cutters. The TBM featured two fixed mounted rock bolt drills behind the finger shield: these were removed and replaced with jacklegs to improve access. A probe drill at the end of the main beam is also present. The geology along the 4.4 km power tunnel comprises very strong and generally massive granitic bedrock with rock strength greater than 225 MPa. A unique feature of the project is that no subsurface investigations have been completed for the tunnel however extensive bedrock outcrops are present along the Ashlu Creek valley. A historical quarry exists approximately mid-way along the tunnel alignment that has exposed good quality granitic bedrock. TBM tunneling to date has achieved advance rates of 10-20 m/day with a maximum of 23 m and has encountered all of the anticipated six major fault zones where the installation of various standard high capacity tunnel support was successfull to facilitate TBM advance through these sections.

TBM and NATM Combined Solution for a Very Deep Tunnel. The "Pajares" Case: *E. Fernandez, P. Navarro* and *A. Sanz,* Dragados, S.A., Madrid, Spain

The rail link between Madrid and the north of Spain encountered in the Cantabrian range the biggest challenge of the whole line. Carboniferous formation along the 24 km tunnel forced to take decisions and substantial changes from the preliminary design to the construction design. Divided the twin tunnel in four different contracts, the centre portion was originally designed to be built by NATM with an access to the main tubes through two vertical shafts 2000 ft. deep. Finally, a decline TBM tunnel 3.4 miles long was the contractor choice to access to the main tunnel with a substantial time schedule savings. NATM big caverns for bifurcation and assembly chambers along the main tunnel and with 2,500 ft. overburden were also challenging issues of the captioned project.

8 M Diameter 7km Long Beles Tailrace Tunnel (Ethiopia) Bored and Lined in Basaltic Formations in Less than 12 Months: *A. Raschilla* and *F. Bartimoccia,* S.E.L.I. Spa, Rome, Italy

On the 2nd of June 2007 SELI S.p.A. started the excavation of Beles Trailrace Tunnel (Ethiopia). The new 8,07 m diameter DS Universal TBM utilized for the tunnel excavation was manufactured by SELI S.p.A. and allowed the installation of 30 cm thick concrete lining, contemporaneously with the excavation of 7,200 m of tunnel. The greatest part of the tunnel alignment was excavated in hard and sound basaltic rocks. The paper describes the main steps of the tunnelling operations which led to a remarkably rapid excavation, with a peak production of 36 m /day and a final breakthrough achieved 46 days ahead of the contractual deadline. Furthermore the paper describes the work and logistic organization that was set up to efficiently perform the mechanized excavation in the very remote area of the project.

Construction of Louisville Water Company's Riverbank Filtration Tunnel and Pump Station Project: *S. Holtermann,* Jordan, Jones & Goulding, Inc., Louisville, KY; *W. Klecan,* Jordan, Jones & Goulding, Inc., Norcross, GA; *K. Ball,* Louisville Water Co., Louisville, KY

Through the process of Riverbank Filtration (RBF), the Louisville Water Company plans to obtain a higher quality source of water for their B.E. Payne Water Treatment Plant (WTP) by means of four collector wells located in the alluvial aquifer along the bank of the Ohio River. The collector wells are connected to a 2,850 L/s (65 mgd) pumping station by a 2,362 m (7,750 ft.) long, 3 m (10 ft.) finished diameter tunnel located in limestone and shale bedrock, which is approximately 45 m (150 ft.) below the surface. High tunnel boring machine (TBM) production rates were achieved in this moderately weak bedrock; most of the tunnel only required support in the crown. An unanticipated water-bearing fault and unanticipated ground behavior proved challenging and required quick thinking to minimize impacts to construction. Tunneling conditions are discussed in detail, together with the methods used for overcoming the groundwater and ground behavior challenges. The tunnel is expected to be completed in April 2009.

Technical Considerations for TBM Tunneling in the Andes: *D. Brox,* Hatch Mott MacDonald, Vancouver, Canada; *R. Valentino Cardoza,* Pacific Hydro, Santiago, Chile; and *G. Venturini,* Sea Consulting, Turin, Italy

The use of Tunnel Boring Machines (TBMs) for tunnel construction of long tunnels in the Andes of South America has been of mixed success in the past due to a variety of reasons and key lessons can be recognized. A review of past TBM tunnel projects in the Andes has unveiled some interesting findings for different TBM tunnel approaches with both world records of progress as well as nearly in-completed projects with machines being abandoned. Key considerations for the use of TBMs for tunnel construction in the Andes include geological issues; (faults, rock type, rock strength, rock abrasivity, durability, groundwater inflows), depth of cover and the potential for overstressing/rockbursts, site access and terrain, portal locations, intermediate access possibilities, minimum tunnel size, support requirements, contractor and labour experience, and project schedule demands. TBMs offer highly recognized schedule benefits (high progress, not concrete lining) for a project if intermediate access adits are limited as well as hydraulic benefits for water conveyance projects. Minimum specifications for TBMs can be easily developed to suit the unique requirements of any project so as long as all factors are carefully considered. The overall conditions and factors associated with some projects may suggest that it is not appropriate to use TBMs due to a perceived high risk. Finally, access for geotechnical investigations by drilling in the commonly steep terrain of the Andes is typically difficult and often not impossible. Alternative approaches for geotechnical investigations for TBM tunnels including comprehensive mapping, high-resolution airborne electric-magnetics for delineation of possible fault zones, and rock block sampling is presented and discussed.

Robbins 10m Double Shield Tunnel Boring Machines on Srisailam Left Bank Canal Tunnel Scheme, Alimineti Madhava Reddy Project, Andhra Pradesh, India: *W. Brundan,* The Robbins Co., Malcha Marg, India

The Srisailam Left Bank Canal (SLBC) Tunnel Scheme is part of the Alimineti Madhava Reddy Project in Andhra Pradesh, South India. This scheme has been planned since 1983 and will provide irrigation facilities to drought-ridden areas in Andhra Pradesh. Water will be transferred from the Srisailam Reservoir during the monsoon months to 0.3 million acres of farmland and will also provide drinking water to villages en-route. The paper will address the design and onsite assembly of the Robbins Double Shield TBMs for Tunnel-1 of the SLBC tunnel scheme from planning to start-up of the machines. Also, it will provide a current status of the project and describe the advantages of a site assembly. Problems encountered to date and the solutions adopted will also be described. The project comprises over 50 km of tunnels and involves construction of the world's longest tunnel without intermediate access. The TBM tunnels at 43.9 km in length and 10.0 m diameter will cross the Amrabad plateau, containing a wild life sanctuary and India's largest tiger reserve, the Rajiv Gandhi. Jaiprakash elected to excavate the tunnel using two tunnel boring machines, rather than by drill and blast, in order to alleviate surface disturbances to environment and the tiger reserve, wild life sanctuary, and protected forestry areas. The Project was awarded to the Main Contractor Jaiprakash Associates Ltd with The Robbins Company as the Tunnel Boring Machine (TBM) supplier in August 2005. The Robbins Company supplied the TBMs along with two continuous conveyor systems and all spares and consumables to complete the tunnel excavation.

Conventional/Rock Tunneling

Monday, June 15 1:30 PM

Chairs: R. Ostoyich, Atkinson Construction, Golden, CO
L. Jennemyr, Skanska USA, Whitestone, NY

High Speed Excavation by Drill & Blast with Mechanized Mucking System – Mitholz Railway Tunnels, Switzerland: *S. Eriksson,* Skanska Infrastructure Development AB, Solna, Sweden

In 2000 the joint venture Satco was awarded the Contract Mitholz for construction of 24 km of the Lötschberg base tunnel in Switzerland. The joint venture consisted of the companies Strabag of Austria, Skanska of Sweden, Vinci of France and Rothpletz and Walo of Switzerland. The construction of the Railway Tunnel through the Swiss Alps with its specific rock conditions started in 2000 and was successfully completed in 2006. This paper will describe the excavation methods by Drill & Blast and modified NATM which were utilized. In particular, the innovative methods adopted to handle the mucking in the extremely long drives of up to 9 km with crushing at face and a conveyor system will be described in detail.

Lake Dorothy Hydroelectric Project Lake Tap and Tunnel, Jeneau, AK: *J. Morrison* and *B. Roberds,* J.S. Redpath Corp., Fernley, NV

The Norwegian Lake Tap Method was successfully used to tap into the side of Lake Dorothy 36.5 m (120') below the lake surface. The lake tap allows water to flow into an access tunnel from the lake lowering the water elevation below its natural outfall. When the lake reaches a predetermined elevation below the outfall, a 1.5 m (60") valve in the tunnel will be shut and discharge from Lake Dorothy will stop temporarily allowing construction of a dam located 2.9 km (1.8 miles) downstream at Bart Lake. The lake tap and tunnel were one phase of the $64 million Lake Dorothy Hydroelectric Project, owned and operated by Alaska Electric Light & Power Company (AEL&P), a private utility located in Juneau, AK. The Lake Dorothy portal site and tunnel are located approximately 25.7 km (16 miles) southeast of Juneau, AK, in the remote Tongass National Forest at an elevation of 701 m (2,300') above sea level in the mountains above the Taku Inlet. Thirty degree snow covered mountainsides and limited access by helicopter were just two of the many factors which challenged this unique project. The lake tap and tunnel development consisted of 250 m (820') of horizontal tunnel, averaging 3.6 m x 3.6 m (12'x12'), excavated using conventional drill and blast methods in highly competent Granodiorite and Tonalite rock placement of one 3.9 m (13') long concrete plug, or bulkhead, located at the tunnel midpoint, and one 3 m (10') diameter lake tap into the side of Lake Dorothy. This paper will provide an analysis of the logistical and engineering challenges involved in development of one of only a handful of lake taps in North America. AEL&P and contractor J.S. Redpath Corporation worked together to complete this critical project phase safely and on schedule, in a location accessible only by helicopter and plagued by constantly changing, harsh weather conditions. A strict schedule had to be maintained to ensure the timely operation of the downstream dam and power plant.

Underground Construction for a Combined Sewer Overflow System in Providence, Rhode Island: *J. Kaplin,* Gilbane, Providence, RI; *J. Peterson,* Jacobs Associates, Burlington, MA and *P.H. Albert,* Narragansett Bay Commission, Providence, RI

The underground construction for the Phase I Combined Sewer Overflow (CSO) Project is on an impressive scale by any measure, appearing more so in a midsize city like Providence, RI. The Narragansett Bay Commission recently completed $350 million in construction to improve the water quality in Narragansett Bay. This project included a number of serious challenges, delays, and disputes. Looking back on this complex project completed within budget, it is hard to consider the work as anything other than a success. Along the way, this outcome did not always appear certain.

Modern Caverns in Gotham-Geotechnical and Design Challenges for Large Rock Caverns in Manhattan: *T. Smirnoff, S. Zlatanic* and *M. Ciancia,* Parsons Brinkerhoff, Los Angeles, CA

The continued investment in rail and subway infrastructure in New York City as resulted in the need for design and construction of large underground caverns in Manhattan as transit hubs. The current plans for stations include The New York Penn Station Extension for the ARC project for New Jersey Transit, and NYCMTA-CCC ambitious expansion with the Cavern stations for the 7 Train at 34th Street beneath 10th Avenue, on 72nd and 86th Streets for the Second Avenue Subway, and the development of twin four track, multi level caverns for the East Side Access project for the Long Island Rail Road at Grand Central station are now under or close to construction.

Tunneling Under the Harlem River: *H. Lacy,* MRCE, East Northport, NY and *J. Mooney,* Consolidated Edison Company of New York, East Northport, NY; and *J. Stypulkowski,* MRCE, East Northport, NY

This paper discusses the challenges faced by the design team of the under-river crossings of electric transmission feeders in New York City, a densely populated urban area. The under-river crossing of a 345 kV feeder was initially designed as Horizontal Directional Drilling (HDD), but was redesigned as a utility tunnel because of site constraints on both sides of the river. Multiple studies addressed location, available technologies and costs. Multiple soil investigation phases addressed design aspects of HDD, as well as tunneling. Contractual issues varied from a design build alternative with Geotechnical Data Report (GDR) to design tender approach with GDR & Geotechnical Baseline Report (GBR).

Design / Planning

Monday, June 15 1:30 PM

Chairs: J. Hurt, Arup, New York, NY
S. Wilson, Jacobs Assoc., San Francisco, CA

Bay Tunnel – Design Challenges: *R.J. Caulfield* and *I. Pawlik,* Jacobs Assoc., San Francisco, CA and *J.I. Wong,* San Francisco Public Utilities Commission, San Francisco, CA

The primary water supply system for the City of San Francisco and adjacent peninsula areas consists of aging and deteriorated pipelines crossing under the San Francisco Bay (the Bay). This system is highly vulnerable to seismic damage from the nearby San Andreas and Hayward fault zones. The Bay Tunnel Project will replace the existing system with a 8-km-long (5 mile long) tunnel underneath the Bay. The tunnel will be constructed using earth pressure balance methods and will have a two-pass lining system of precast concrete bolted, gasketed segments for initial support, and a welded steel pipe final lining. The project challenges include tunneling through both soft ground and rock conditions without any intermediate shaft access over the entire alignment. Seismic performance criteria include maintaining service flows after a large earthquake.

The Selection of Excavation Methods for the Detroit Upper Rouge Tunnel CSO Control Project: *J. Habimana,* Jacobs Engineering, Detroit, MI; *W.P. Chen,* Jacobs Engineering, Boston, MA; *R. Barbour,* Jacobs Engineering, Detroit, MI; and *P. Turner, G. Stoll, Jr.,* and *M. Rabbaig,* Detroit Water and Sewage Dept., Detroit, MI

Complex and distinct geological units spread along the 7 mile long 30 ft. inside diameter Upper Rouge Tunnel CSO Control Project in Detroit, Michigan. Its construction is divided in two tunnel construction packages. The South Tunnel, to be driven in finely laminated weak TG Limy Shale, will be excavated by a shielded TBM with precast concrete segmental lining, while the North tunnel, predominatly in a relatively more competent geologic formation Antrim Shale, will be excavated by a main beam TBM with a two-pass lining system. The adits and deaeration chambers will be excavated by sequential excavation method. This paper addresses the process of selecting excavation methods and lining systems for shafts, tunnels, connecting adits, and deaeration chambers.

Planning and Design Features of the Waller Creek Tunnel, Austin, Texas: *G. Jackson* and *S. Evans,* City of Austin, Austin, TX; *T. Saczynski,* Kellogg Brown & Root, Yucaipa, CA; *P. Jewell,* Kellogg Brown & Root, Dallas, TX; and *P. Donde,* Jenney Engineering Corp., Springfield, NJ

Preliminary engineering for the Waller Creek Tunnel was completed in 2001, but the project was held in abeyance until the summer of 2007. This paper describes several features of the revised design, which required significant changes from the original concept. Most notable is the expected replacement of a tunnel boring machine (TBM) by conventional tunneling. The considerable influence of geological conditions on the tunnel vertical alignment is discussed, in particular the impact of the zones of Eagle Ford Shale with swelling potential. Other features which are described include the wide span tunnels and large diameter shaft requirements.

NATM Strategies in the U.S. – Lessons Learned from the Initial Support Design for the Caldecott 4th Bore: *B. Thapa,* Jacobs Assoc., San Francisco, CA; *T. Marcher*, ILF Consult, Innsbruck, Austria; *M. McRae,* Jacobs Assoc., San Francisco, CA; *M. John,* Tunnel Consult, Innsbruck, Austria; *Z. Skovajsova,* ILF Consult, Oakland, CA; and *M. Momenzadeh,* California Department of Transportation, CA

The design of the Caldecott 4th Bore, located along State Route 24 in Oakland, California, is based on the principles of the New Austrian Tunneling Method (NATM). Typical NATM initial support design practices used in Europe were adapted for this project to account for U.S. conditions and requirements, such as degree of experience with NATM construction, the prevailing contractual environment, and preferences for contractual simplicity. Key design features are: (1) support selection criteria based on ground behaviors and ground conditions; (2) a perscriptive design with allowance for support adjustments based on observations during construction; and (3) organization of support requirements into only four major support categories, while permitting some adjustment for variations in ground behaviors and conditions using a few subtypes and additional support measures.

The Price is Right – Planning Large Water Tunnel Contracts in New York: *C. Maguire,* URS, Columbus, OH

Tunnel contracts in New York have in recent years had few bidders with the bids received being much higher than anticipated. Since 9/11, security has become a key issue in planning key infrastructure projects in New York. This is especially true in the case of large water supply tunnels. Striking the right balance between cost and security was the major factor in determining the best configuration for the Kensico-City Tunnel. This paper outlines the efforts made to determine realistic probable bid costs for the tunnel contracts, and the innovative approaches taken to deal with security issues.

Daylighting Thorn Creek Tunnel into Chicago's TARP Thornton Composite Reservoir: *C. Hirner,* Black & Veatch, Kansas City, MO; *K. Fitzpatrick* and *M. Landis,* Metropolitan Water Reclamation District of Greater Chicago, Chicago, IL; and *F. Oksuz,* Black & Veatch, Chicago, IL

The Metropolitan Water Reclamation District of Greater Chicago is in the final phase of completing the Calumet System componet of Chicago's Tunnel and Reservoir Plan (TARP) by bringing the Thornton Composite Reservoir online by 2014. The existing 22 foot diameter Thorn Creek tunnel that conveys flood water to the adjacent transitional reservoir will be rerouted to the new reservoir. The planned drill-blast tunnel connection is located in the quarry highwall directly below Interstate I-294/80. The project features an access shaft, tunnel, control gate, energy dissipating structure, bulkheads, and live tunnel connection, and will be procured in late 2009.

Shafts

Monday, June 15 1:30 PM

Chairs: G. Hauser, Jay Dee Contractors, Livonia, MI
S. Hoffman, Skanska, Whitestone, NY

New Technology Changes Blind Shaft Drilling: *A. Zeni,* Frontier Kemper Constructors, Evansville, IN

Frontier-Kemper's DHI 240 is a state-of-the-art 240 ton blind drill rig capable of drilling 8 ft. - 20 ft. diameter shafts to depths in excess of 1,000 ft. In addition, blind shaft drilling is easily adopted for urban environments where noise and other restrictions are of concern.

Tamerlane Hoist and Vertical Belt Project: *S. Collins,* FKC – Lake Shore, Evansville, IN

FKC-Lake Shore has been involved in the development of a special test project with Tamerlane Ventures Inc. which includes a combined vertical belt and service hoisting system in a single 22 ft. diameter shaft. The project is located in the Northwest Territory of Canada at the Pine Point mine on the south shore of Great Slave Lake. Tamerlane Ventures Inc. has presented a new approach to try to mine this prentiful Lead-Zinc deposit while avoiding the problems encountered previously. The shaft and related hoist/belt systems will be constructed within a large frozen perimeter to prevent heavy local groundwater from infiltrating the work area.

A Small Diameter Shaft Design Alternative: *B.E. Gombos* and *D.P. DiPonio,* Wade Trim Assoc., Detroit, MI

During early stages of the detailed design for Detroit's Upper Rouge CSO Tunnel Project, a Value Engineering Recommendation suggested the design team investigate alternative concepts to the usual cast-in-place or precast concrete lining system for the Project's many smaller diameter Deaeration Vent Shafts. The resulting design investigation produced not only an alternative lining system, but lead to a proposed non-conventional approach to shaft installation means and methods through soil and rock necessary to construct the permanent shaft lining system. This paper will outline and summarize the technical issues, contractual restrictions, and cost considerations that eventually lead to the final shaft design.

Kansas River Tunnel Shaft Drilling: *C. Haynes* and *C. Hirner,* Black & Veatch, Detroit, MI; *D. Smith,* Johnson County Water District No. 1, Lenexa, KS; *C. Griffith,* Southland Contracting, Inc., Fort Worth, TX; and *B. Lawler,* ATS Drilling, L.P., Fort Worth, TX

While the Kansas River Tunnel is a relatively short, small diameter tunnel, the shaft excavation methods implemented were long and large on innovation and use of reverse circulation drilling equipment. ATS Drilling, L.P. used mechanical excavation techniques for both soil and rock segments of the 42.7 m (140 feet) and 38.1 m (125 feet) deep shafts that were 2.9 m (9.5 feet) and 4.1 m (13.5 feet) diameter, respectively.

Design Considerations for the Use of Slurry Walls as Permanent Walls for Deep Rectangular Shaft Structures in Seismic Areas-Silicon Valley Rapid Transit Project: *M. Lehnen,* Hatch Mott MacDonald, San Jose, CA; *C. Wu,* Sunrise Pacific Inc.; *M. Wongkaew,* Hatch Mott MacDonald, San Jose, CA; and *J. Chai,* Santa Clara Valley Transportation Authority, Santa Clara, CA

Slurry diaphragm walls are commonly used as both temporary excavation support walls, and permanent structural walls, for circular shafts and long rectangular structures (such as underground subway stations); however, they are not commonly used for more compact rectangular or square shafts. In these instances, a second wall is typically cast inside the slurry walls to form the permanent structure. This paper discusses the approach used on the Silicon Valley Rapid Transit Project in California to analyze these compact rectangular types of structures for static and seismic loading, and to determine whether or not slurry walls can be confidently used as both the temporary and permanent walls for two tunnel ventilation shafts.

Slurry / EPB I

Monday, June 15 1:30 PM

Chairs: D. Liebno, Obayashi, Washington, DC
L. Calin, Kenny Construction, Los Angeles, CA

Selection, Design, and Procurement of North America's Largest Mixshield TBM for Portland, Oregon's East Side CSO Tunnel: *C. Metzger,* Kiewit Bilfinger Berger JV, Portland, OR; *G. Colzani,* Jacobs Assoc., Portland, OR; and *G. Irwin,* City of Portland Oregon, Bureau of Environmental Services, Portland, OR

This paper discusses the process utilized by the Kiewit-Bilfinger Berger Joint Venture (Contractor) to select, design, and procure the largest mixshield tunnel boring machine (TBM) ever implemented in North America. The mixshield will excavate the 8,534 linear m x 6.7 m ID (28,000 linear ft. x 22 ft. ID) tunnel for the City of Portland Oregon's Bureau of Environmental Service (Owner) East Side CSO Tunnel Project. TBM selection was conducted under a preconstruction contract in which the Contractor, Owner, Construction Management Consultant and Designer collaborated on TBM selection prior to commencement of construction. This paper focuses on TBM design considerations, including the use of one versus two machines, machine configuration, extended-wear protection, hyperbaric interventions, boulder digestion, and erection of a steel-fiber-reinforced segmental lining.

Construction of Drilled Shafts for the Upper Northwest Interceptor, Sections 1 & 2 Project – Sacramento, CA: *J. Theys,* Traylor Brothers Inc., Sacramento, CA and *C. Schafer,* Hayward Baker, Inc., Concord, CA

The Sacramento Regional County Sanitation District (SRCSD) is improving the sewer system in the Natomas area of Sacramento, CA. The Upper Northwest Interceptor (UNWI) system is an ongoing series of tunnel pipeline projects that will provide sewer conveyance for all residents of northeast Sacramento County to the New Natomas Pumping Station, located North of downtown Sacramento, also in the city of Sacramento limits. The New Natomas Pumping Station then carries wastewater flows to the Sacramento Regional Wastewater Treatment Plant in Elk Grove via the existing Lower Northwest Interceptor. The Jont Venture of Traylor Brothers, Inc. and J.F. Shea (TSJV) were awarded the UNWI 1 & 2 Project in late September, 2007. The planned 5.8 km (3.65 mile) construction route for UNWI 1 & 2 begins at the New Natomas Pump Station and runs north along the East Drainage Canal to the beginning of UNWI 3 & 4 at Bridgecross Drive. UNWI 1 & 2 includes approximately 5.8 km (19,240 ft.) of 3.65 m (144 in.) inside diameter pipe using Earth Pressure Balance Tunneling Methods. The project also includes 16.76 m (55 ft.) of 3.04 m (120 in.) diameter interceptor pipeline, twenty three access manholes spaced approximately 305 m (1,000 ft.) apart along the alignment, a 2.13 m (84 in.) by 3.65 m (144 in.) transition structure, a 3.65 m (144 in.) by 3.04 m (120 in.) transition structure, and the connection of three existing sanitary sewer lines to the interceptor.

Port Authority of Alleghany County North Shore Connector Project Tunnels and Station Shell Case History Contracts 003 and 006: *P. Zick,* Obayashi/Trumbull JV, Pittsburgh, PA

The Port Authority of Allegheny County North Shore Connector (NSC) Project involves TBM excavation of twin 690 m (2,240 lf) precast segment lined light rail tunnels through soil and rock under the Allegheny River and a narrow, downtown city street. The $435 M project is funded 80% ($348 M) by the Federal Government, 17% ($72.5 M) by the State of Pennsylvania and 3% ($14.5 M) by Allegheny County. Along the tunnel alignment are a historic building on shallow foundations, modern buildings on deep foundations, and one building constructed directly over the alignment. The project includes construction of twin 369 m (1200 lf) cut and cover concrete box tunnels and an underground station shell. This papeer provides an overview of general site conditions, current project status and construction challenges for the Twin Tunnels and North Shore Light Rail Station.

Construction of the North Dorchester Bay CSO Storage Tunnel in Boston: *J. Davies,* Hatch Mott MacDonald, Westwood, MA; *K. Chin,* Massachusetts Water Resources Authority, Charlestown, MA; *J. Ohnigian,* Shaw Environmental & Infrastructure, Stoughton, MA; and *J. Stokes,* M.L. Shank, San Meteo, CA

This paper describes the successful management and construction of the 5.18 m (17 ft.) diameter, segmentally lined, North Dorchester Bay CSO storage tunnel in Boston, MA. This 3300 m (10,830 ft.) long tunnel was mined through vairable soft ground with only 6 m (20 ft.) of cover, using an earth pressure balance tunnel boring machine. These extensive data collected from the projects unique automated and internet accessible geotechnical and TBM monitoring system, will be examined and used to explore the relationships between geological conditions, TBM operating parameters and measured settlements. The paper will also discuss the use of screw revolutions as an indicator of muck volume.

High Risk Tunneling Adjacent to Large Water Tank on the UNWI Sections 3 & 4 Project: *A. Finney,* CH2M Hill, Sacramento, CA; *J. Wong,* Sacramento County Sanitation District Authority, Sacramento, CA; *C. Vandaelle,* Michels Tunneling, New Berlin, WI; *C. Painter,* PB Americas, Rio Linda, CA; and *S. Cano,* KBR, New Port Beach, CA

The Sacramento Regional County Santitation District's Upper Northwest Interceptor Sections 3 & 4 Project involved construction of reinforced concrete pipe installed using a 102 in. EPBM. A foundation design change made during construction of an adjacent water storage reservoir resulted in the challenge of tunneling within 6 ft. of a 3 million gallon reservoir bearing on a shallow foundation while within clean sands and a shallow groundwater table. The solution to mitigating additonal settlement risk involved a joint collaboration between the owner, CM, designer, and contractor. The issues of design and construction of the successful joint solution are presented along with data on the predicted and actual lateral and axial ground movements.

Construction Works of Large – Section Vertically Parallel Twin Tunnels in Close Proximity: *K. Kuraji* and *M. Morita,* Metropolitan Expressway Co., Tokyo, Japan and *N. Araki* and *Y. Taniguchi,* SHIMIZU Corp., Tokyo, Japan

This report describes construction works of 12.65 m diameter vertically parallel twin tunnels for two-lane highway in close proximity using a slurry type TBM (Slurry Shield Tunnel). This project is located on Metropolitan Expressway Central Circular Shinjyuku Route in Tokyo. Driving along a 123.5 m radius sharp curve alignment, the TBM excavates the upper tunnel passing under the existing highway viaduct piers and subway tunnels. At the arrival shaft, the 2100 ton TBM is jacked down by hydraulic jacks installed on the shaft wall and is made a U-turn to excavate the lower tunnel. The minimum distance between the two tunnels is 1.4 m.

A Practical Approach for Precast Concrete Segmental Ring Selection: *S. Skelhorn* and *L. McNally,* McNally Construction Inc., Toronto, Canada

Over the recent year, major advances have been made in design of precast concrete segmental tunnel liner. Starting from basic, parallel sided rings, we now have state of the art, universal rings incorporating custom tapers to suit individual requirements. At planning stage, the ring diameter is normally fixed and the ring geometry is one of the first items to be assessed. Obvious factors such as TBM layout and curve radius can constrain geometry; however, there are other factors that should be considered in order to optimize production. This paper takes a look at the history of the segmental rings and criteria for ring selection, including: general ring geometry; individual segment geometry; ring taper, and ring width. This paper also explores optimization of ring with a focus on constructability.

Technical Program

Innovation

Tuesday, June 16 8:30 AM

Chairs: J. Smith, Brierley Assoc., Liverpool, NY
P. Helsop, Arup

Uetliberg Tunnel: Soft Ground Excavation and Premiere of New Tunneling Machine; World's First Tunnel Bore Extender Excavated by Undercutting: *S. Maurhofer,* Amberg Engineering Ltd., Regensdorf-Watt, Switzerland and *H.P. Müller,* Amberg Technologies Ltd., Regensdorf-Watt, Switzerland

The Uetliberg Tunnel in Switzerland is the longest tunnel in Zurich's new Western Bypass Expressway, connecting the Birmensdorf bypass in the west with the existing Zurich-Chur national motorway in the east. Thus the tunnel links the Zurich-West motorway interchange with the Zurich-South interchange. The Uetliberg Tunnel project comprises two parallel tubes, each about 4.4 km long. The two tunnel tubes are connected every 300 m by a transverse walkway and every 900 m by a transverse roadway. The SOS niches are spaced 150 m apart. Portal stations with machinery rooms are located at the west and east portals. The tunnel falls with a gradient of 1.6% from the west portal at Wannenboden to the east portal at Gänziloo. The Project costs are about CHF 1.12 billion. The carcass construction started in March 2001. The opening of the Uetliberg Tunnel is planned in spring 2009.

Extensible Conveyor Systems for Long Tunnels Without Intermediate Access: *D. Workman,* The Robbins Co., Oak Hill, WV

Long extensible conveyor systems are an important option for efficient tunnel excavation where intermediate access is impractical. The conveyor system designed for the Pula Subbaiah Veligonda Tunnel #2 in Andhra Pradesh, India will eventually extend to 19.35 km. The Ø10.0 m water diversion tunnel will be excavated under India's largest tiger sanctuary using a Robbins Double Shield TBM. Once extended, the conveyor will be one of the longest single-flight systems ever installed in India, and is expected to offer increased system availability over comparable systems using muck cars. This paper will examine the engineering challenges of long-flight extensible conveyor systems in the areas of belt selection, component design, and equipment location in confined assembly and launch areas.

New Cutter Soil Mixing (CSM) Technology Used to Construct Microtunneling Shafts for Mokelumne River Crossing: *M. Wallin* and *M. Asperger,* Bennett Trenchless Engineers, Folsom, CA

A part of the East Bay Municipal Utility District's Folsom South Canal Connection Project, 430 ft. of raw water pipe was installed using microtunneling beneath the Mokelumne River. The access shafts for this crossing were constructed 50 to 35 ft. deep through very dense sands and soft sandstone and siltstone. High groundwater and the immediate source of recharge from the river required watertight shaft construction methods. The shaft contractor, Drill Tech of Antioch, CA, used a brand new Bauer cutter-soil mixing (CSM) rig to construct the large shafts. The structural concept is similar to secant piles, but instead of creating cylinders of soilcrete, the CSM rig creates interlocking rectangular panels. This technology has been used previously in Europe, Asia, and Canada, but this was the first project to use CSM technology in the United States. Cutter-soil mixing technology has other applications beyond shaft construction, including retaining wall construction and levee reinforcement.

An Introduction to Virtual Design and Construction (VDC): *M. Rheinlander,* Parsons Brinkerhoff, Brisbane, Australia; *R. Arulraj,* Parsons Brinkerhoff, New York, NY; *A. Hobson,* Parsons Brinkerhoff, New York, NY; and *C. Graham,* Parsons Brinkerhoff, Brisbane, Australia

The paper will describe Virtual Design and Construction (VDC) as a tool which will enable us to build a project "virtually" on a computer before constructing and operating it in the real world. VDC computer models are built, using information from various sources including survey, 3D laser scanning, CAD and GIS to represent the project and its components in a coordinated and consolidated infrastructure model. This model is reviewed and evaluated by, and shared among project teams including owners, contractors, designers, engineers, construction managers, stakeholders and operators. It allows teams to fix costly design and construction issues before construction onsite. Benefits and lessons learned from global projects will be discussed.

Placement of Concrete Lining for Water Tunnel #3, Manhattan Portion: *R. Labbe* and *M. Gorski,* Schiavone Construction Co., Wappinger Falls, NY

The final tunnel lining for this project involved pumping vast quantities of concrete over large distances. Approximately 68,000 cubic meters (89,000 cubic yards) were pumped from various locations over 152 meters (500 ft.) below ground to create nearly 14.5 kilometers (9 miles) of 3.05 meter (10 ft.) diameter tunnel under lower Manhattan. Total distances pumped exceeded 1645 meters (5400 ft.) horizontally after a vertical difference of over 152 meters (500 ft.). The urban setting of the operation, coupled with the long distances over which concrete was pumped, created many problems that had to be dealt with along the way. A three-shift labor operation was implemented to allow sequential pouring of tunnel sections nearly every day, and fine tuning the mix design was critical to make this possible.

New Projects II

Tuesday, June 16 8:30 AM

Chairs: J. Kennedy, Atkinson Construction, Golden, CO
D. Young, Hatch Mott MacDonald, Pleasanton, CA

Design of NATM Tunnels and Stations of Silver Line Phase III Project in Boston: *V. Nasri,* AECOM, New York, NY; *K. Vrouvlianis,* AECOM, Boston, MA; and *I. Halim,* URS Corp., Boston, MA

The Silver Line Phase III Project is the final one mile underground segment of the new Bus Rapid Transit in downtown Boston. The project is expected to significantly reduce existing and anticipated traffic congestion. The twin one-lane tunnels and two station platforms will be built by NATM in Boston saturated soft clay, sand and till layers in proximity to several historical buildings, underpinning two existing cut and cover subway stations and several major utilities in densely built urban area. This paper presents the analysis and design of the NATM tunnels and stations detailing the excavation sequence and support system and various ground improvement and pre-support techniques used in the preliminary and final design of the project.

Geotechnical and Structural Design Challenges of the Fremont Central Park Subway for the BART Warm Springs Extension: *M. Fong, S. Owyang,* and *T. Lee,* Parsons Brinkerhoff, San Francisco, CA

The Bay Area Rapid Transit (BART) District will be extending BART service south along an 8.7 km (5.4 mile) long corridor in the city of Fremont, California as part of the Warm Springs Extension (WSX). The WSX project will link the existing BART system to the future BART to San Jose extension. A segment of WSX is located in Fremont Central Park (referred to as the Fremont Central Park Subway Project). The Fremont Central Park Subway is considered the most complicated and geotechnically challenging portion of the project with an underground subway box being constructed near the active Hayward Fault which is capable of ground motions up to 0.75g and is located in an aquifer which is used for water storage and supply. Soil-structure interaction analysis was used in the design of the subway box to resist deformations due to earthquake ground motions. A water-tight excavation support system has been designed to allow subway box construction while minimizing impacts to the aquifer.

Atlantic North South Tunnel: *S. Sadek* and *H. Caspe,* HNTB Corp., Boston, MA; *T. Heilmeier,* HNTB, Atlanta, GA; and *D. VanMeter* and *J. Hancock,* Georgia Department of Transportation, Atlanta, GA

The Georgia Department of Transportation (GDOT) undertook an exploratory feasibility study to one of the most ambitious tunneling projects in the United States. HNTB Corporation was retained to perform the study, deemed the Atlanta North-South Tunnel, which is approximately 7 miles long and consisting of four lanes (or six lanes) starting at the southern terminus of SR 400 extending to the south connecting with the northern terminus of I-675, providing substantial relief to the Downtown Connector (I-75/I-85), the most congested portion of Atlanta's freeway system. This paper summarizes the analysis performed during the first phase of the challenging assignment which, if constructed, would be one of the longest roadway tunnels ever built in the United States.

Proposed Contracting Practices for the Caltrain Downtown Extension: *D. Penrice* and *B. Townsend,* Hatch Mott MacDonald, San Francisco, CA

The Caltrain Downtown Extension (DTX) project will extend commuter and future statewide high-speed rail service into the Transbay Transit Center, which will be located in the business district in downtown San Francisco. The DTX project includes 1.5 miles of underground construction, comprising complex sections of mined and cut-and -cover tunnel. As part of the DTX preliminary engineering process, development of appropriate contracting practices, including contract packaging, procurement methods and contract terms for the underground construction, has been initiated. This paper provides a summary of the evaluations undertaken, preliminary conclusions reached, and proposed next steps to promote industry interest and maximize bid competition.

NYC

Tuesday, June 16 8:30 AM

Chairs: B. Roberts, Parsons Brinkerhoff, New York, NY
D. Hickey, Judlau, Brooklyn, NY

Alternative Final Cavern Linings for the East Side Access Transit Project: *C. Barratt* and *W. Cao,* Parsons Brinkerhoff, New York, NY

The East Side Access (ESA) project is the largest underground rail infrastructure project under construction in New York City, USA. The Manhattan segment of the project is to be mined through rock and consists of 4.1 miles of Tunnel Boring Machine tunnels for track work and mined excavations to house rail switches, air plenums, and other rail facilities. This paper considers different methods for concrete lining, such as the use of fixed forms, adjustable forms, and pneumatically applied shotcrete. The advantages and disadvantages of these methods are discussed and the basis for considering one over the other are illustrated. Further discussions on design development and preparation of documents to facilitate quality and constructability in the field are presented.

Continuing the Legacy: An Update on the Construction of the New Second Avenue Subway: *J. Sankar* and *C. Bennett,* AECOM Transportation, New York, NY; *D. Caiden,* Arup, New York, NY; *A Parikh,* MTA Capitol Construction, New York, NY; and *T. Peyton,* Parsons Brinkerhoff, New York, NY

The dream of constructing the new Second Avenue Subway in New York has finally become reality as the first construction contract package is currently underway. This first contract requires the construction of a TBM Launch Box in the middle of Second Avenue from which a Tunnel Boring Machine (TBM) will bore two tunnels south to 63rd Street. This paper will discuss the design of this contract and how construction has progressed including preparation, site constraints, utility construction and community impacts while highlighting the challenges of working in an urban environment. It will also discuss moving forward on this major project outlining the remaining contract packages including their scope and status.

No. 7 Subway Extension Crossing Under an Existing Subway Station: Challenges and Integration of Underpinning into the Design of New Tunnels: *A. Grigoryan,* PB Americas, Ridgewood, NJ

This paper addresses the challenges of designing the underpinning of major subway station with 4 operating tracks. No. 7 subway extension crosses under the existing 42nd street subway station on the 8th Avenue line. Understanding the history of the original construction, of the current structures and their condition were instrumental in developing a feasible underpinning design that is integrated with the design of the new tunnels. The existing 8th Avenue subway station has a lower abandoned level. Several alignments and corresponding underpinning schemes were studied. The design allows new tunnel construction under the station without interruption of station operations.

Railroad Interface Management for MTA East Side Access Project Tunnels and Structures: *M. Piepenburg,* Hatch Mott MacDonald, Long Island, NY; *D. Louis,* MTACC/URS Corp., New York, NY; *R. Magnifico,* Metropolitan Transit Authority, Long Island City, NY; and *A. Juliano,* Amtrak, New York, NY

The East Side Access (ESA) Project will extend Long Island Rail Road (LIRR) into midtown Manhattan via 11 km of tunnels, a new terminal station and associated support facilities. In addition to the hard-rock tunneling currently underway in Manhattan, soft-ground tunnels in Queens will traverse beneath Amtrak's Sunnyside Yard and Harold Interlocking, the busiest rail interlocking in North America. This paper details ESA's coordinated approach to interfacing with both Amtrak and LIRR with regard to the planned tunnels, shafts and related construction beneath or adjacent to the operating railroads. This interface includes integration of the railroad staff, extensive presentations, reviews and agreements with the railroads regarding settlement mitigation, real-time automated geo-instrumentation monitoring, ground improvement, and geotechnical/environmental controls.

Construction of the MCUA Tunnel and Force Mains Under the Raritan River, New Jersey, A Case History: *B. Rautenberg,* Kenny Construction Co.; J. Prada and *F. Perrone,* Hatch Mott MacDonald; *D. Tanzi,* Middlesex County Utilities Authority

The Construction of Tunnel and Edison Force Mains contract involves the installation of two new force mains to provide a redundant means for sewage conveyance from Middlesex County Utility Authority's (MCUA) Edison Pump Station on the northern shore of the Raritan River to the Central Wastewater Treatment Plant on the southern shore. The force mains will be installed in a 1,192 m (3,910 lineal ft.) long tunnel with a 4.09 m (13'-5") inside diameter, fully gasketed precast concrete segmental lining, which is to be tunneled underneath the Raritan River utilizing an Earth Pressure Balance TBM. The tunnel is anticipated to encounter flowing soils near and beneath the river. Two new 60 in. diameter Centrifugal Cast Fiberglass Reinforced Polymer Mortar force mains will be installed within the tunnel leaving an open utility corridor above the force mains for future consideration. The project also includes the design and construction of two slurry wall shafts with associated piping. The paper wil provide an overview of design and provide a case history of the construction of the tunnel and highlights of the construction methods implemented to date.

TBM Case Histories II

Tuesday, June 16 8:30 AM

Chairs: E. Eisold, Bradshaw Construction Corp., Ellicott City, MD
B. Zernich, Traylor Brother Inc., Lakeside, CA

Madiq Tunnel, Lebanon TBM Tunneling vs. Karst Geology: *W. Leech,* MWH Americas, Scottsdale, AZ; *I.B. Jaoude,* Baresel AG/ Al Tajj, JV, Brommana, Lebanon; and *N. Ghanem,* Beirut, Lebanon

Lebanon used a TBM for the first time to excavate a tunnel in the country. A main beam TBM, built in 1979, bored the 3.8 m (12.5 ft.) diameter by 4,020 m (2.5 miles) Madiq Tunnel. The TBM bored through karstic terrain of dolomitic limestone, limestone and marly-limestone rock having near horizontal beds with more than twelve faults crossing the axis of the tunnel. The TBM also encountered more than six major karst features, filled with various combinations of boulders, clay, void space and water. The excavation through these collapsed-breccia zones drastically slowed the TBM's progress. When complete, which the Madiq Tunnel is a part, the Kesrouane Water Project along the coast will bring fresh and irrigation waters to the parched and heavily populated region north of Beirut. The paper will describe the tunnel geologic features, karst genius, TBM upgrades and performance, and TBM/karst difficult situations.

Onsite Assembly and Hard Rock Tunneling at the Jinping-II Hydropower Station Power Tunnel Project: *S. Smading, J. Roby,* and *D. Willis,* The Robbins Co., Kent, WA

Unique onsite assembly of a 12.43 m Main Beam TBM and back-up system was completed on September 18, 2008 in the remote mountains of the Sichuan province of China. The equipment was assembled onsite, without previously having been assembled and tested in a factory, utilizing a method called Onsite First Time Assembly (OFTA). The Jinping-II hydroelectric project features four parallel headrace tunnels approximately 18 km long, two of which will be excavated by TBMs and two by drill and blast. A nearby fifth tunnel is being excavated by a 7.2 m TBM to draw down ground water in advance of excavating the headrace tunnels.

Double Shield TBM in Challenging Difficult Ground Conditions – A Case Study from Zagros Long Water Transfer Tunnel, Iran: *J.K. Hamidi* and *K. Shahriar,* Amirkabir University of Technology, Tehan, Iran and *J. Rostami,* Pennsylvania State University, University Park, PA

The Zagros long tunnel is one of the main components of Sirvan water transfer project in western Iran. It is approximately 48 km in length and consisted of two lots. The second 26 km lot of this tunnel is under construction by a 6.73 m diameter double shield (DS) TBM. The tunnel passes through several formations with wide range rock mass qualities. During the tunnel alignment, changes in rock quality were highly frequent from poor to very good. The encountered geological conditions required TBM operation to change frequently from hard rock to soft, dry to flowing, sticky to nonsticky ground (and vice versa), more often than expected. In the course of tunneling, the machine has encountered nearly many adverse geologic conditions. The most important problems have been sudden high volume water inflow into the tunnel, sticky ground, and gas seepage, all of which resulted in reduced TBM advance rates. This study will highlight two difficult ground conditions including large water ingress and sticky ground and also the related problems encountered by the TBM along 8 km of excavated tunnel. In sticky grounds, cleaning of the clogged cutterhead caused many delays and contributed to additional downtime. Application of some operational modifications, including decreased TBM thrust showed satisfactory results in such cases. While reduced thrust resulted in reduced penetration rate, but the overall TBM advance was greatly improved by the increase utilization rate and elimination of down time related to cleaning of the head. To cope with high water inflow, application of preventive measures such as pre-grouting has proved to be a more efficient solution. The sealing of ground water inflow also decreased seepage of dangerous H_2S gas and other chemicals such as hydrocarbons accompanying the groundwater.

Impacts of Ground Convergence on TBM Performance in Ghomroud Tunnel: *E. Farrokh* and *J. Rostami,* Pennsylvania State University, University Park, PA

Ghomroud water conveyance tunnel project is under construction using shield Tunnel Boring Machines (TBM) for a total length in excess of 50 km. Phase 1 of the project included 36 km of tunnel divided into four lots (1, 2, 3, and 4) of nine km each. Lots 3 and 4 of this tunnel for a total length of 18 km were combined into one award and have been constructed using a double shield (DS) TBM or one path system. Extreme ground convergence in some sections of the tunnel has stalled TBM performance in early reaches, due to face collapse and shield jammings. This paper presents the latest update on the tunnel progress and impact of ground convergence on machine performance based on the information obtained from field observations. Also, the method and results of tunnel convergence measurements were studied in conjunction with geological parameters and an attempt was made to correlate TBM operational parameters and ground convergence. The result of the analysis indicates a good correlation between machine's operational parameter and tunnel convergence and can be used as an indicator of the potential for high rates of convergence. An early warning on ground convergence is essential for taking precautionary measures to avoid TBM jamming and related long delays and costs.

TBM Data Management and Quality Assurance for the Brightwater Conveyance Project: *J. Mitsopoulos*, Jacobs Engineering, Field Services North America, Inc., Bothell, WA; *F. Stahl,* Babendererde Engineers GmbH, Bad Schwartau, Germany; *J. Wonneberg,* Jacobs Engineering, Field Services North America, Inc., Bothell, WA; and *K. Rossi,* EPC Consultants

King County's (KC) Brightwater Conveyance Project in Seattle, Washington involves the construction of approximately 21 kilometers (13 miles) of bored tunnel, in three contracts, with four TBM's which produce large amounts of real-time digital mining data. To facilitate the management of TBM data with a single interface and assist in project Quality Assurance, KC's Construction Manager (Jacobs Engineering) recommended the use of the software TPC (Tunneling Process Control), developed by Babendererde Engineers GmbH. The paper demonstrates how TPC was used for oversight, analysis and QA on a complex tunneling project and how contemporaneous review and management of data results in a better understanding of TBM performance than can be obtained by retrospective analysis of data.

Construction of the East Side Access Manhattan Tunnels: *D. Hickey,* Judlau, Brooklyn, NY

The MTA in conjunction with LIRR, are in the process of expanding one of the largest commuter railroads in the country, with over 260,000 passengers a day. The LIRR, which provides 700 passenger trains every 24 hours, can't continue on the present growth course as a joint tenant in Penn Station with Amtrak and NJT. For this reason, in conjunction with the fact that over 53% of LIRR's current riders into Penn Station are ultimately bound for the East Side of Manhattan opening, have created the need for expansion of the LIRR. The complete expansion will cost approximately 6.3 billion dollars and all of the contracts are to be completed by 2013.

Geotechnical

Tuesday, June 16 1:30 PM

Chairs: **C. Locke,** King County DNRP, Bothell, WA
M. Kucker, Shannon & Wilson, Seattle, WA

Geotechnical Baseline Reports – A Review: *T. Freeman,* GeoPentech, Santa Ana, CA; *S. Klein,* Jacobs Assoc., San Francisco, CA; *G. Korbin,* Lafayette, CA; and *W. Quick,* Talmo, GA

In the past ten years, the Geotechnical Baseline Report (GBR) has arguably become the key document for tunnel construction. This report not only allocates much of the risk involved with the work, it serves as the basis for bid preparation and is used extensively in resolving disputes during construction. This paper discusses some important issues related to the GBR and presents suggestions for improving these vital reports.

Ground Characterization for CSO Tunnels in Washington D.C.: *M. Ponti,* Camp Dresser & McKee, Cambridge, MA; S. *Fradkin* and *M. Wone,* Hatch Mott MacDonald, Arlington, VA; *X. Wang,* Camp Dresser & McKee, Falls Church, VA; *R. Bizzarri,* District of Columbia Water & Sewer Authority, Washington, D.C.; *E. Cording,* University of Illinois at Urbana-Champaign, Savannah, GA; *R. Ilsley,* Roktek Geotechnical Inc., Topanga, CA; and *Q. Kazmi,* Schnabel Engineering

The D.C. Water and Sewer Authority is implementing the Anacostia River Projects component of its Long-Term CSO Control Plan, including 21 kilometers of 3.7 to 7 meter diameter CSO near-surface diversion storage/conveyance structures and flood relief, pressurized-face, soft ground tunnels at a maximum depth of 65 meters. This paper describes a project-specific soil grouping system that is primarily based on soil characteristics for tunneling derived from tests including Atterberg limits, grain size, swelling, mineralogy, triaxial, pressuremeter, and consolidation, which differentiates the project from past area tunnel projects using descriptive systems based primarily on area geology.

Actual vs. Baseline Tracking During TBM Tunneling in Highly Variable Glacial Geology: *U. Gwildis* and *J. Newby,* CDM, Bellevue, WA and *L. Maday,* King County DNRP, Bothell, WA

The Brightwater Conveyance System includes 21 km of tunnels mined by two earth pressure balance Tunnel Boring Machines (TBMs) and two slurry TBMs. The probabilistic baseline approach defined in the Geotechnical Baseline Report (GBR) can representatively be verified by use of a comprehensive tracking system to identify face conditions that allows comparison with the baselines. The glacial geology includes a high lateral variation in soil types that, when combined with the pressurized face tunneling methods, creates challenges for documenting face conditions. Baseline tracking using spoil samples and TBM operational parameters provides information to document actual conditions and support resolution of differing site condition claims.

Assessing Ground Ahead of TBM Tunnel Using Low-Interruption Wireless Seismic Reflector Tracking System: *T. Yamamoto* and *Y. Yokota,* KAJIMA Technical Research, Tokyo, Japan; *J. Descour,* KAJIMA Technical Research, Littleton, CO; and *M. Kohlhaas,* KAJIMA Technical Research, Jamestown, CO

High-speed TBM excavation requires rapid ground assessment ahead of excavation, particularly in complex grounds. The Tunnel Reflector Tracing technology (TRT) developed by authors, uses seismic reflections to produce volumetic images of ground anomalies. To further minimize interruption in the TBM excavation the authors modified surveying technique switching from cable (wired) to radio (wireless) data acquisition system. This paper presents the outline of the Wireless TRT system, and compares the results for the wired and the wireless surveys. The comparison shows that the wireless system offers high precision data, is more efficient and economical and significantly less intrusive in tunneling operations.

Ground Characterization and Feasibility Evaluation of Tunneling Methods for Mather Interceptor: *M. Jafari,* Camp Dresser & McKee, Providence, RH; *M. Middleton* and *B. Corwin,* Camp Dresser & McKee, Sacramento, CA; and *A. Page,* Sacramento Regional County Sanitation District, Rancho Cordova, CA

The Camp Dresser & McKee (CDM) has been retained by the Sacramento Regional County Sanitation District (SRCSD) to design the Mather Interceptor, a portion of the South Interceptor and Mather Interceptor program. The Mather Interceptor consists of 14,667 feet of 54 to 72 inch gravity interceptor. Approximately 90 percent of the alignment will be constructed via tunneling. Cobbles and boulders in a sand/gravel matrix dominate the ground conditions combined with seasonal perched groundwater table at some of the deeper reaches of the alignment, impacting design consideration. This paper will present the results of a comprehensive geotechnical investigation conducted for this project and in-depth technical evaluation of various trenchless techniques feasible for tunneling in the cobble and boulder laden formations of this project. This paper will also present the risks and issues of the design alternatives and selection criteria.

Ground Modification

Tuesday, June 16 1:30 PM

Chairs: **J. Kaneshiro,** Parsons Brinkerhoff, San Diego, CA
P. Roy, AECOM USA, New York, NY

North 27th Street ISS Extension Unique Owner/Contractor Agreement Settles Major Disputes: *D. Olson,* CH2M Hill, Milwaukee, WI; *R. Maurer,* MMSD, Milwaukee, WI; and *M. Vliegenthart,* J.F. Shea, Wauwatosa, WI

The North 27th St. ISS Extension tunnel will, under present plans, be the last constructed section of Milwaukee Metropolitan Sewerage District's (MMSD's) existing deep tunnel system. The 6.5 m (21 ft.) finished diameter tunnel is approximately 3260 m (10,590 ft.) long and is located in NE Milwaukee County. When disputes over the processes to be used in owner-directed pre-excavation grouting in rock threatened the completion date stipulated between MMSD and the Sate of Wisconsin, the MMSD and J.F. Shea, the contractor, entered into a unique agreement. Shea accepted responsibility for all shaft and tunnel grouting and water control during the project in exchange for settlement of claims related to grout quantites and perceived delays. This significantly reduced risk for the MMSD and helped ensure the stipulated completion of the project.

Brightwater Conveyance System: Ground Freezing for Access Shaft Excavation Through Soft Ground: *J. McCann, D. Mueller, and P. Schmall,* Moretrench, Rockaway, NJ and *J. Nickerson,* Frontier Kemper Constructors, Inc., Seattle, WA

The Brightwater regional wastewater treatment facility, under construction in King County, WA, includes an extensive conveyance system that will feature deep, soft-ground tunnels and shafts. Excavation of the Ballinger Way Receiving Portal to 65.8 m (216 ft.) below grade through challenging geology was accomplished by means of artificial ground freezing. This paper discusses freeze design development, system installation and monitoring, and the contractual and construction challenges that were overcome, including work sequencing and excavation means and methods, together with lessons learned.

New Approach of ASFINAG for Tunnel Construction Monitoring of the Tauern Tunnel Project in Austria: *R. Schnabl,* ASFINAG, Innsbruck, Austria and *J. Mayr,* DIBIT Messtechnik GmbH, Innsbruck, Austria

New approach of ASFINAG for tunnel construction monitoring of the Tauern Tunnel Project in Austria. ASFINAG is responsible for the construction and operation of the Austrian highway system. It is approx. 2,400 km of highways and 65 tunnels with a total length of 200 km including the Tauern Tunnel. In order to improve the documentation of the tunnel construction, ASFINAG chose to use a state of the art tunnel scanning system to record the various stages of construction: excavation, initial shotcrete lining, smoothing layer and final cast in place concrete lining. The geometric and photogrammetric documentation is provided on a daily basis to all parties involved. This innovative concept provides accurate & complete information in real time. The tunnel scanner documentation of the 2nd tube at the 6.4 km long Tauern Tunnel will be presented in this paper as part of the survey contract.

Research in Soil Conditioning for EPB Tunneling Through Difficult Soils: *R. Ball, D. Young,* and *J. Isaacson,* Hatch Mott MacDonald, Pleasanton, CA and *J. Champa* and *C. Gause,* BASF Construction Chemicals, LLC, Cleveland, OH

The excavation of difficult soils by means of an Earth Pressure Balance Machine (EPBM) creates the potential for a reduced advance rate and increased downtime. EPBMs typically use soil conditioning to modify soil behavior to reduce abrasion, reduce cutterhead torque, control water, and ensure control of the spoil passing through the screw conveyor. Recent research is presented concerning two difficult soils for EPBM tunneling, which are sticky soils and coarse grained soils with low fines content. Soil conditioning tests were performed on several samples of difficult soils, which provide insight into how different polymers and additives can modify soil behavior to improve the performance of EPBM mining. During testing, the use of high density slurry to augment soils with low fines content was investigated. Results of investigation and a review of available literature is presented to help predict the potential for machine clogging and to help select useful soil conditioning agents in soils with low fines.

An Analysis Method for Modeling Compensation of Settlements Due to Tunnel Driving by Grouting Cement Suspensions: *C. Wawrzyniak,* CDM Consult GmbH, Stuttgart, Germany and *W. Krajewski,* University of Applied Sciences, Darmstadt, Germany

An analysis method for modeling compensation grouting based on the finite element method is presented. By this method the design parameters of compensation grouting, grouting pressure and grouting volume, can be evaluated. Also the subsidence of a building due to tunnel driving as well as the lifting of the building by compensation grouting can be simulated. The stress changes in the tunnel lining and in the foundation of the building are computed as well. The application of the analysis method is demonstrated on two examples for compensation grouting in combination with construction of tunnels.

SEM

Tuesday, June 16 1:30 PM

Chairs: J. Habimana, Jacobs Engineering Grp, Detroit, MI
S. Wimmer, Kiewit, Omaha, NE

Case History of the Wachovia – Knight Theater Pedestrian Tunnels: *E. Eisold,* Bradshaw Construction Corp., Ellicott City, MD and *P. Donde* and *I. Tarchala,* Jenny Engineering Corp., Springfield, NJ

The Wachovia Headquarters and Arts and Cultural Campus project in Charlotte, NC includes a 1.5 million square foot, 48-story office tower, two museums, an Afro-American cultural center and a 1,200 seat theater for the performing arts. Public access to the Cultural Campus is through two pedestrian tunnels constructed under city streets connecting to parking garages. The 5.7 m wide by 4.7 m high mined tunnels were procured through a design-build contract. The tunnels were designed as initial/final shotcrete linings with a sprayed water barrier sandwiched between layers of shotcrete. In addition, the mix design was supplemented with a cementitious admixture to develop internal water resistant properties in the shotcrete.

Boggo Road Busway Project, Brisbane, Australia: *T. Nye* and *M. Kitson,* Sinclair Knight Merz, St. Leonards, Australia and *R. Chinniah,* Sinclair Knight Merz, South Brisbane, Australia

This paper describes a number of aspects of the design and construction of a driven tunnel which forms part of the Boggo Road Busway Project. The driven tunnel is 430 m long with an excavated width of 15 m and full tunnel excavation height of 8 m. The first section of driven tunnel was excavated under the heritage listed Boggo Road Jail for a length of 120 m. The main jail buildings and perimeter walls were built in 1908 and are of bick construction. Ground cover over the tunnel beneath the jail site varied from 5.5 m to 8 m and as a consequence the predicted settlement values and their potential to cause damage to the buildings were critical to determining and obtaining approval for the selected tunnel alignment. The geology along the driven tunnel alignment was very variable, providing mixed face tunneling conditions and ranging from surface residual soils to high strength rock at depth. The maximum ground cover above the driven tunnel is 20 m.

Loosening and Face Stability with Shallow Overburden in the "SITINA Tunnel", Bratislava, Slovakia: *C. Tanimoto,* Taisei, San Francisco, CA; *K. Tsusaka,* Japan Atomic Energy Agency, Horonobe, Japan; *T. Aoki,* Taisei Corp., Sofia, Bulgaria; and *M. Iwano,* Taisei Corp., Shinjuku, Japan

The SITINA Tunnel has been constructed as a part of D2 Motorway, linking between Czech and Hungary through Bratislava. The tunnel consists of two tubes with the length of 1,415 and 1,440 m, respectively. It has been driven through granitic rock formation, which was specified as heavily faulted and remarkably weathered. The overburden thickness was about 30 m at maximum. The standard cross-section was in the range of 80 to 100 m2, respectively. The excavation took 21 months from September 2003 to May 2005. The construction is based on the concept of NATM. In driving through the difficult geological situation the excavation work hit 49 faults, and some of them occasionally caused serious face instability. They caused the vertically predominant displacement at the crown, namely 39 mm at maximum in the vertical direction and 27.5 mm at maximum in the horizontal direction. Averagely, the vertical displacement was approximately 40% higher than the horizontal one. The auxiliary reinforcement with the 4 to 8 m long pipe roofing was needed to protect the vicinity of mining face area. This operation extraordinarily required additional works and time which had not been expected before construction. In this paper, the characteristic manner of deformation in the vertically jointed rock formation and quantifying the loosening are presented as well as the lessons obtained in NATM.

Innovative NATM – Design for a Large Shallow Cavern at Stanford: *T. Marcher* and *M. John,* ILF Consulting Engineers, Innsbruck, Austria and *S. Matthei* and *Z. Skovajsova,* ILF Consulting Engineers, Oakland, CA

Stanford Linear Accelerator Center (SLAC) is located in Menlo Park, CA. In order to allow for enhanced experiments, the current facilities required expansion. Tunnels were excavated through very weak sedimentary rock interspersed with uncemented zones (Ladera Sandstone) employing the principles of the NATM. The overburden varied from 10 to 80 feet. The paper addresses the characterization of Ladera Sandstone that can exhibit the properties of dense sand and weak rock. The paper focuses on the challenges that were encountered during the NATM initial support design and the construction phase including the geotechnical instrumentation, monitoring and design verification process in practicular the excavation of the junction between access tunnel and the FEH cavern (49 ft, wide by 32 ft. high).

ADECO – RS as an Alternative to NATM: How it Works, Why it Works: *F. Tonon;* University of Texas, Austin, TX

And Rabcewicz said "tunnels should be driven full face whenever possible". ADECO, which stands for "Analysis of Controlled Deformations in Tunnels", now allows us to fulfill Rabcewicz's dream in any stress-strain condition. The paper presents the basic concepts in the ADECO approach to design, construction and monitoring of tunnels together with some case histories, including: full face excavation for Cassia tunnel (width of 22 m, height of 14 m) in sands and silts under 5 m cover below an archeological area in Rome, Italy; Tartaguille tunnel (face area> 100m^2) advanced full face in highly swelling and squeezing ground under 100 m cover where NATM led to catastrophic failure, France; and 80 km of tunnels (face area> 100 m^2) advanced full face in highly squeezing/swelling ground under 500 m cover for the high-speed railway line between Bologne and Florence, Italy (turnkey contract).

Technical Program

Slurry / EPB II

Tuesday, June 16 1:30 PM

Chairs: L. McNally, McNally Construction Inc., Toronto, Canada
S. Skelhorn, McNally Construction Inc., Toronto, Canada

Big Walnut Outfall Augmentation Sewer-Part II TBM Case History: *T. Szaraz* and *G. Bulla,* McNally Kiewit JV, Westlake, OH and *C. Smith*, CRS Consultants, Chicago, IL

Part of a major sewer expansion for the City of Columbus, Ohio. The Big Walnut Outfall Augmentation Sewer – Part II (BWOAS) consists of 13,200 ft. of tunnel of 12 ft. tunnel passing mainly through glacial deposits with a water head of up to 2 bar. A Lovat RME167SE was used to drive this tunnel with steel fiber reinforced precast segmental liner used for support. This paper will discuss the concepts for tunnel support and TBM selection, the problems encountered with the TBM sealing systems and the solutions used to repair the machine.

EPB Tunneling Through Cohesionless Saturated Ground Under Very Shallow Cover-Perth New MetroRail City Project: *H. Yamazaki,* Leighton Contractors, Brisbane, Australia; *O. Sigl,* Geoconsult Asia Singapore Pte Ltd, Singapore; *F. Aikawa,* Leighton-Kumagai JV, Brisbane, Australia; *R. Bhargava,* Parsons Brinkerhoff, Brisbane, Australia

The paper describes prediction, control and validation of face pressures, and special TBM features for the bored tunnels of the New MetroRail City Project, Perth, Australia. The selected EPB-TBM passed below a heritage bridge and the operational Perth Railway station in ground conditions consisting of fully saturated uniform sand combined with shallow overburden and a horizontal alignment radius of only 135m. Therefore, strict control of volume loss, TBM operations and ground movements was vital requiring continuous evaluation and adjustments to TBM operation parameters. The paper discusses the effectiveness of applied TBM face pressures and the used foam/polymer soil conditioning which was measured against achieved volume loss and the predicted range of ground settlements.

Sao Paulo Metro Project-Control of Settlements in Variable Soil Conditions Through EPB Pressure and Biocomponent Backfill Grout: *L. Pellegrini* and *P. Perruzza,* SELI S.p.A. Rome, Italy

The respect of EPB reference pressure during TBM advance and hyperbaric activities, the complete and effective filling of the annular gap between tunnel lining extrados and the excavation section and a well organized monitoring system, to control surface settlements and ground distortion, are items of utmost importance in EPB tunnelling process. The paper describes how these concepts have been applied while excavating in the difficult underground conditions found at Sao Paulo (Brazil) during the execution of the Sao Paulo Metro Line 4 – Lot 1. In this project, the annular gap has been filled by two components type, cement grouting. The back feed of the extensive monitoring campaign carried out to check the surface settlements during the excavation and hyperbaric maintenance operations will also be described in the paper.

Planning and Preparation for Tunneling at Brightwater West: *M. Shinouda* and *G. Frank,* Jay Dee Contractors, Shoreline, WA and *G. Hauser,* Jay Dee Contractors, Livonia, MI

Brightwater West (BT4) represents the state of the art in utility tunneling, namely a long relatively small diameter, soft ground tunnel, with no intermediate shafts, under significant groundwater pressures, requiring very precise survey control in order to hit a small exit window. The tunnel is over 6.4 km (4 miles) in length, is expected to encounter active earth pressures of over 5 bars in glacial geology, and a planned hole through into a shaft eye constructed at 45.7 meter (150 ft.) below the water table. Despite the fact that all of these challenges have been previously overcome in larger diameter tunnels, the technical solutions are much more challengining in a smaller diameter due to the lack of space available for implementing the equipment and techniques required. In addition to the technical challenges, the project is faced with many of the constraints designed to minimize the impact of these types of projects on the neighboring community and environment. The work shaft for BT4 is within 15.2 m (50 ft.) of Puget Sound and is on a site that was previously occupied by the petroleum storage tanks, and all of the tunnel muck has to be removed from the site by barge as trucking is not allowed by contract. The paper addresses the work performed during the preparation for tunneling stage of this project both in assembling the TBM and in preparing the site for its arrival.

Brightwater East – A Case History: *L. Calin* and *T. Hupfauf,* Kenny Construction Co., Los Angeles, CA

King County (Seattle, WA) is on a monumental task of building the new Brightwater System complete with a new treatment plant, three main conveyance tunnels, a new outfall into Puget Sound and other ancillary works. This paper will describe the first conveyance tunnel, Brightwater East currently under construction by the Joint Venture of Kenny (Sponsor) / Shea / Traylor that is scheduled for completion in early 2010. The project located in Bothell, WA (north of Seattle) is in both King and Snohomish Counties. It was the first of the major tunnel projects that was scheduled by King County for the Brightwater System. The East Contract consists of the following major elements: 14,000 ft. of 19'-2" EPBTBM mined tunnel using 16'-8" ID bolted, gasketed precast concrete segments for a primary liner; installing and encasing 14,200 ft. each of 48", 66", 27", 84" in diameter steel pipes inside the tunnel along with three runs of fiber optic cable; 2,430 ft. of 72" diameter microtunnel including three caisson shafts and associated structures; one Intercepting Structure (IS) shell to mine from that is 74 ft. deep and 74 ft. finished in diameter with 130 ft. deep slurry diaphragm walls, tremie slab and final concrete wall lining; one Influent Pump Station shell (IPS) 83 ft. deep, twin 77 ft. inside diameter cells, with 160 ft. deep slurry diaphragm walls, tremie slab, and final lining; two short 12 ft. in diameter inter-shaft connector tunnels; one extraction shaft 40 ft. deep by 40 ft. wide and 140 ft. long for connection to the new treatment plant piping.

Gotthard-Base Tunnel, Section Faido Previous Experience with the Use of the TBM: *M. Herrenknecht, O. Bockli,* and *K. Bappler,* Herrenknecht AG, Schwanau, Germany

After the successful breakthrough at the end of 2006 of both TBMs into the multifunctional site Faido (MFS), in the middle of 2007 the two tunnel boring machines resumed the 12 km long section between Faido and Sedrun. In the roughly a 10 month interval both approximately 425 m long tunnel boring machines were partly dismantled, pushed through the 2.5 km long MFS, rebuilt for the new larger diameter of 9.5 m and reassembled to be ready for operation. In the rebuilding phase, improvements were made to the equipment, especially as a result of experience gained from the previous 12 km long drive in the section Bodio and taking into account the latest information regarding the upcoming 12 km section Faido. Both TBM drives are currently in the rock formations of the Lucomagno gneiss, which stretch over a section of 3.5 km from the MFS Faido to the predicted Piora Syncline. This section is divided into two fold axes of the Chiéra Synform, where Lucomagno gneiss pass from a sub-horizontal into vertical bedding. The drives, with current rock overburdens exceeding 1,500 m and, as know from the excavation phase of the MFS, in part highly disturbed rock formations, are characterized by the locally intense rock squeezing conditions with large convergences in the vicinity of the driving TBM as well as backwards due to the interaction of the two drives. High expenditure for the support measures, reduced driving performances together with extensive extra work associated with deadlines and increased costs are the result. In the paper the previous experience with the TBM drives in the section Faido and the challenges still awaiting us are presented and discussed.

International

Wednesday, June 17 8:30 AM

Chairs: H. Ivory, URS Corp., Columbus, OH
I. Lamb, Jacobs Assoc., Seattle, WA

The Hallandsås Dual Mode TBM: *W. Burger,* Herrenknecht AG, Schwanau, Germany and *F. Dudouit,* Skanska-Vinci HB, Forslov, Sweden

The Hallandsås project with a long history, first started in 1991, is well known in the tunneling community. In the past it has been stopped twice for technical and environmental reasons. The third attempt started in 2004 using a dual mode rock TBM. The heterogeneous highly fractured and abrasive rock mass as well as large areas of water bearing zones present most difficult subsurface conditions. The tunneling concept is based on the use of watertight segmental lining and a TBM able to operate in open mode, possibilities for extensive pre excavation grouting and high pressure closed mode operation up to 13 bar to cover exceptional conditions.

Effective Planning of Underground Space – Planning and Implementation of the First Undergound Water Reservoirs in Hong Honk: *T. Chan,* Water Supplies Department, Hong Kong; *D. Arnold,* Black & Veatch, Las Vegas, NV; and *E. Chung* and *C. Chan,* Black & Veatch, Kowloon, Japan

As the University of Hong Kong and their advisors planned their new Centennial Campus it became clear that they would have to re-provide existing water reservoirs on an adjacent site with new salt water reservoirs located underground in two new caverns. The existing reservoirs are owned by the Water Supplies Department who provide salt water for sanitary flushing and a separate potable water supply for regular use. Although underground reservoirs had not previously been adopted locally, the planning has been completed to a tight schedule and the construction is well advanced. The need to preserve historic buildings imposed constraints, as did the requirement to minimize potential construction nuisance for the local community and environment. This paper presents the background to the project and the work carried out to develop an innovative, sustainable and environmental acceptable solution. Construction progress to date is also presented.

Hobson and Rosedale Tunnels – New Technology in Auckland: *H. Asche* and *T. Ireland,* Connell Wagner, Auckland, New Zealand; *M. Sheffield,* Watercare Services Ltd., Newmarket, New Zealand; and *M. Bonnette,* McConnell Dowell Constructors, Mt. Wellington, New Zealand

The last 12 months has seen the construction of the first Earth Pressure Balance (EPB) TBM excavated tunnel in New Zealand on the Project Hobson sewer storage tunnel for Watercare Services Limited, with the concurrent excavation of the second EPB tunnel on the Rosedale Outfall project for North Shore City Council. Together these tunnels involve a total length of 6 km and follow an 8 year pause in TBM activity in Auckland. TBM performance on these two projects is thus of significant interest as there are four major tunneling projects totaling over NZ$8B being planned for Auckland, in similar ground conditions. Auckland's bedrock is a weak sandstone/siltstone (East Coast Bays Formation), subject to infilled paleovalleys. The geology in the region has been significantly influenced by volcanic activity; 49 volcanoes are present within 20 km of the city centre. The paper describes the design and construction challenges for the projects, including TBM performance, "sticky soil" management, and risks associated with basalt lava flows and two paleovalleys. Watercare's Project Hobson also saw the successful implementation of a Geotechnical Baseline Report – one of the first uses of this type of document in Australasia. Rosedale Outfall is designed for high internal water pressures with varying hydraulic flows, with the risk of exfiltration explicitly addressed.

Feasibility and Implementation of Shield Machine Tunnel Passing Through the Operating Airport Runway: *H. Yang, X. Wang,* and *H. Liu,* Shanghai Shentong Railway & Consultancy Co., Ltd., Shanghai, China

The No. 10 metro line of Shanghai city is 36 kilometers in length and will pass through the operating airport runway by using tunnel boring machine with earth pressure balance mode. Although there are examples through world that tunnels pass through airport runway and tunnelling underground is not a difficult undertaking technically, there is rare experience in China for the similar projects especially in Shanghai saturated soft soil region. Shanghai soft earth is famous for its high compressibility, high rate of water content, weakness in strength, large deformation and different characteristics in earth strata. Besides, the whole construction process will be under ultra-large airplane dynamic load on the surface ground over the tunnel, which increases the risks of construction process. This paper evaluates the feasibility of building the metro tunnel under such an extremely serious condition, expecially the subsidence of ground surface caused by advancing of tunnel boring machine, which also is the most important control target for the safe operating of the runway. Furthermore, this paper discusses the effective measures to keep the settlements in the permissible level during the whole working period for the tunnel from aspects of plan, design and construction.

Experience Gained in Mechanical and Conventional Excavations in Long Alpine Tunnels in Switzerland: *Y. Boissonnas,* Amberg Engineering Ltd., Regensdorf-Watt, Switzerland

The transalpine rail routes in Switzerland are well over one hundred years old. As the established routes no longer meet the demands of the continually increasing volumes of rail traffic between north and south, two new routes through the Alps were planned. The old Gotthard rail line is in fact a mountain railway. The northern and the southern access ramps – with a maximum speed of 80 km/h and a maximum slope of 2.2% – reach the old Gotthard rail tunnel at an elevation of approximately 1,100 m above sea level. This is approximately 900 m higher than the city of Milan. In 1992, the Swiss electorate people voted with an overwhelming majority in favor of the project to build the new base routes through the Alps. The Swiss voted again in 1998 in favor of the financing proposal for the new infrastructure. Swiss Federal Railways together with the BLS Lötschbergbahn were commissioned for the realization and management of the Gotthard and Lötschberg routes. Alp Transit Gotthard Ltd., founded by Swiss Federal Railways, was given the task of managing the design and realization of the Gotthard route until the start of regular service. In the meantime the shorter Lötschberg Base Tunnel was open to traffic in 2007.

Microtunnel

Wednesday, June 17 8:30 AM

Chairs: **G. Irwin,** City of Portland Environmental Services, Portland, OR
B. Austell, Coluccio Construction, Seattle, WA

Microtunneling 1.2 Mile, 72-IN RCP with Crossings of NJ Turnpike and CSX Railroads: *Z. Cai,* Hatch Mott MacDonald, New York, NY; *A. Solana,* Northeast Remsco Construction, Farmingdale, NJ; and *N. O'Connor* and *P. Lloyd,* Hatch Mott MacDonald, New York, NY

The ongoing Overpeck Valley Parallel Sewer Project of Bergen County Utilities Authority (BCUA), New Jersey, is a US $65 million CSO improvement program to meet a State DEP consent order by 2010. One major program component includes a total of 1,8 km (1.2 mile) long, 1800 mm (72 in.) diameter reinforced concrete pipe (RCP) installed by a Herrenknecht AVND1800AB MTBM. The alignment includes drives through 850 m (2788 ft.) of extremely soft glaciolacustrine varved clay, 980 m (3214 ft.) of loose to medium dense mixed soils containing silty sands, gravels, and boulders, and crosses under the New Jersey Turnpike, US Highway Route 46, and a CSX Railroad Intermodal Yard and a branch mainline. Two types of MTBM cutterheads are being used, one configured for the weak varved clay, and one for the mixed soil conditions. The MTBM is also equipped with a double-steering system consisting of a standard front steering joint and a second trailing steering joint to assist grade control should adequate steering not be achieved by the front primary steering in extremely weak soil conditions. This paper discusses the significant engineering aspects and challenges related to site settings, ground characterization, key MTBM features and performance, and required ground treatment.

The Longest Drive – Portlands's CSO Microtunnels: *C. Overby,* Bureau of Environmental Services Portland OR, Portland, OR; *M. Roberts*, Kiewit-Bilfinger Berger (KBB) J.V., Portland, OR; and *C. Kolell,* Jacobs Assoc., Portland, OR

As part of the City of Portland, Oregon's East Side Combined Sewer Overflow Tunnel Project, nine separate 2130 mm (84-in.) diameter reinforced concrete pipe microtunnel drives totaling approximately 2380 m (7,808 ft.) are being constructed to divert flows from several of the existing outfalls to the main tunnel. The drives were constructed in challenging ground conditions that include soft soils under the groundwater table, large amounts of wood and metal debris, and close proximity to sensitive structures. While all of the drives will be addressed, the focus of the paper will be on the 931 m (3,055 ft.) continuous drive connecting Outfall 46, currently the longest microtunnel driven in North America.

Microtunnels vs. EPB Risk Based Selection: *M. Ramos* and *K. Staheli,* Staheli Trenchless Consultants, Seattle, WA

The Ballard Siphon was build in 1935 and conveys sewage under Seattle's Salmon Bay. It consists of twin 36 in. 1,365 ft. long inverted wood-stave siphons. In 2005, King County performed a sonar condition survey of the Ballard Siphon in which it appeared the crown of the siphon was intruding. This prompted King County to issue an emergency replacement declaration. Staheli Trenchless Consultants (STC) performed feasibility and design iterations for trecnchless replacement options. Completion of re-surveying and cleaning resulted in new sonar information showing grease along the crown. King County down-graded the project from emergency status but kept an accelerated schedule and added capacity improvements. Multiple pipe configurations were considered. STC proposed slip-lining the existing siphons resulting in a 9 million dollar savings to King County. The preferred design consists of twin 30 in. high flow pipes and a 2,000 ft. 85 in. low flow pipeline installed using either microtunneling or EPB shield construction. The latter method was chosen after assessing the risks involved, both engineering and non-engineering. This paper presents the approach used to assess risk along with the decision making process; including factors such as public perception and perceived constructability to select construction methods.

Microtunneling Challenges in Soft Ground of Downtown Hartford, CT: *W. Bergeson, V. Nasri,* and *J. Sullivan,* AECOM, New York, NY; and *A. Pelletier,* Hartford Metropolitan District Commission

This paper presents the challenges of the Hampstead Avenue Interceptor Extension (HAIE) project in downtown Hartford, Connecticut. The new 72 in. (1,830 mm) sewer pipeline project consists of installing approximately 3,010 linear ft. (920 m) of PVC lined reinforced concrete pipe using pressurized face microtunneling. The entire alignment is located within soft to very soft, varved silt and clay. To the extent possible, the alignment was selected to avoid bedrock, glacial till, miscellaneous fill, buried steel piles, and utilities. Challenges for this project include low ground cover, crossing major transportation routes, and limiting settlement to prevent damage to historical buildings and critical utilities. The machine was selected for the ground conditions. Design calculations were performed for selecting the reinforced concrete pipe class and for evaluating settlement. The potential for settlement damage was evaluated using both conventional analysis and finite element analysis.

Microtunneling for Utilities Under Harold Railroad Interlocking: *W. Reininger* and *R. Pociopa,* STV Inc., New York, NY and *W. Lee,* Parsons Brinkerhoff, New York, NY

Microtunneling provides a necessary solution for multiple utility crossings associated with the New York Metropolitan Transportation Authority Capital Construction Company's (MTACC) Eastside Access Project for the Long Island Rail Road. Construction of four TBM tunnels and their approach structures at the eastern end of the project in Sunnyside, Queens required significant modification and expansion of the railroad infrastructure at this location. Maintenance of railroad traffic during project construction is a principal requirement. As a consequence fourteen (14) utility crossing segments are being installed under active traffic by microtunneling methods. Microtunnels were installed in a variety of conditions including depths, types of soils and construction restraints.

Technical Program

Mining

Wednesday, June 17 8:30 AM

Chairs: **T. Yokota,** Frontier Kemper, Kenmore, WA
L. Jacobs, Frontier Kemper, Pelham, NY

Technical Challenges in Mine Rehabilitation: *D. Dodds,* North Pacific Research, Portland, OR; *D. Clayton,* Clayton & Assoc., Polson, MT; and *T. Johnson,* Spokane, WA

Much has been written about Iron Mountain Mine. Some of its reputation is deserved and some is not. The project is interesting because the mine conditions were extreme, the environmental aspects of the project were challenging, limited geotechnical data was available and finally the team had only a 6 month period for design. The ambient temperature is about 58° C with humidity of 100 percent. The pH of the water in the mine ranges from 7.0 to 0.0. The impact of the acid water on design and construction was significant; neither concrete nor steel responds well to pH below 2.5. Much uncertainty surrounded this three-year project, however, it was finished with no deaths, no loss time accidents and no claims, on schedule and on budget.

Open Pit TBM Driven Drainage Tunnel – OK TEDI Mine: *T. Peach,* Terratec, Blacksmans Bay, Tasmania and *N. Sugden,* OK TEDI Mine LTD, Hamilton Central, Australia

OK Tedi Mining Company operates an open pit copper-gold mine in the Highlands of Papua New Guinea. The mine plan, was for the open pit to cease and to be self draining in February 2009. In July 2007 the mine decided to bore a drainage tunnel under the mine. To have the drain in place in the remaining time available, it was necessary to purchase a TBM and subsequently engage a contractor to construct the tunnel and drainage structures. This paper gives details of the major project risks that were identified and the measures adopted to mitigate them. Particular attention is paid to the risks associated with the procurement of the TBM. Details are provided of the issues associated with the TBM selection process, the logistics of re-manufacturing, transporting the machine to the project site, and assembling at the project site in tropical wet conditions. At the time of writing this abstract the tunneling is 50% complete.

The Deep Underground Science and Engineering Laboratory and the Construction of Physics Megacaverns: *C. Laughton,* Fermi Research Alliance, Batavia, IL

The Deep Underground Science and Engineering Laboratory (DUSEL) is to be constructed at the defunct Homestake Mine, in South Dakota. As a cornerstone of DUSEL's research program, it is intended to conduct experiments into the fundamental nature of neutrino and proton particles. The experimental apparatus required to conduct these experiments will be housed in large rock cavern(s) sited at depths of over a kilometer. As conceived, these cavern(s) are planned to have mined volumes of up to half a million cubic meters, and spans of approximately 50 meters.

Subsurface Repository Ventilation Design: *E. Thomas,* Bechtel SAIC LLC, Las Vegas, NV and *J. Gonzales,* U.S. Department of Energy, Las Vegas, NV

The U.S. Department of Energy's Yucca Mountain Project is a geologic repository project designed to receive, handle, package, transport, and emplace spent nuclear fuel and high level radioactive waste. The planned repository would be located in Yucca Mountain on the western edge of the Nevada Test Site, about 90 miles northwest of Las Vegas, Nevada, and would include both surface and subsurface areas. Yucca Mountain rock formations consist of successive layers of volcanic rocks (called tuffs) approximately 14 to 11.5 million years old, formed by eruptions of volcanic calderas to the north. With the volcanic rock the potential for methane emission is not an issue and the subsurface repository is a non-gassy (methane) classification.